VDA
Engineers'

PROCEEDINGS

—OF—

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

PITTSBURGH, PA.

VOL. XVIII.

1902.

CONTENTS

GEORGE H. BROWNE,

FOURTH PRESIDENT OF THE SOCIETY, 1885.

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FOURTH PRESIDENT OF THE SOCIETY, 1885.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The twenty-second annual meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn Avenue, Pittsburg, Pa., Tuesday evening, January 21st, 1902, Mr. H. W. Fisher being in the chair and forty members and visitors being present.

Among those present were the following Past Presidents: William Metcalf, E. B. Taylor, T. P. Roberts, T. H. Johnson, Charles Davis, Emil Swensson and William A. Bole.

The meeting was called to order at 8.45 o'clock, and the minutes of the preceding annual meeting were read and approved.

The following reports were read:

REPORT OF TREASURER FOR YEAR ENDING JANUARY 21, 1902.

Jan. 15, 1901.

To balance.. $ 745 59

RECEIPTS.

Dues to January,	1899, at	$7 00,		2	$ 14 00
" "	1900, at	5 00,		1	5 00
" "	1900, at	7 00,		7	49 00
" "	1901, at	5 00,		7	35 00
" "	1901, at	7 00,		22	154 00
" "	1901, at	7 00,	¾ year,	2	10 50
" "	1901, at	7 00,	¼ year,	1	1 75
" "	1902, at	5 00,		59	295 00
" "	1902, at	7 00,		282	1,974 00
" "	1902, at	5 00,	¾ year,	2	7 50
" "	1902, at	7 00,		282	115 50
" "	1902, at	7 00,	½ year,	2	7 00
" "	1902, at	7 00,	¼ year,	19	33 25
" "	1902, at	5 00,		5	25 00
" "	1902, at	7 00,		26	182 00

Initiation fees (82)	410 00	
Rent	906 00	
Sale of Proceedings	370 07	
Advertising in Proceedings	98 00	
Special contribution to library	3 00	
Received on account	7 25	
		$4,702 82
		$5,448 41

EXPENDITURES.

Salary of Secretary	$ 600 00	
Rent	1,545 00	
Office expenses	269 34	
Stenographer	147 50	
Printing	1,262 55	
Illustrations in Proceedings	121 45	
Commissions	28 80	
Repairs and improvements	87 28	
Periodicals	18 90	
Gas	165 37	
Water	55 13	
Insurance	20 00	
Miscellaneous	1 71	
		$4,323 03
Balance, January 15, 1902		1,125 38
		$5,448 41
Amount on hand as Special Lunch Fund	$ 14 74	
" " deposit for keys	25 00	
" " Building Fund	1,119 07	
		1,158 81
Total balance, January 21, 1902		$2,284 19

A. E. FROST, *Treasurer.*

We hereby certify that we have examined the above accounts for the year 1901, and found them to be correct.

H. J. LEWIS,
CHAS. DAVIS,
Auditing Committee.

January 13, 1902.

REPORT OF SECRETARY FOR YEAR ENDING JAN. 21, 1902.

Members at close of year ending Jan. 15, 1901		410
At the annual meeting, January 15, 1901, there were six (6) names dropped from the roll	6	
There were thirteen (13) resignations, and one (1) death during the year	14	
A total loss of	20	
During the year two (2) of the applicants elected in 1890 matriculated	2	
During the year ninty-two (92) applicants were elected members of the Society, and of these seventy-eight (78) matriculated	78	
A total gain of	80	
Making a net gain of		60
The total membership, January 21, 1902, being		470

The average attendance at the regular meetings of the Society during the year was forty-five (45).

C. W. Ridinger,
Secretary.

REPORT OF BOARD OF DIRECTION.

The Board of Direction recommends the expulsion of the following members for non-payment of dues, the Secretary having made every reasonable effort to collect the dues and having notified the members of the intended action of the Society: Messrs. C. W. Ehlers, E. D. Frohman, H. J. Hohl, J. E. Porter, R. A. Rowland and Paul S. Whitman.

It was voted that the reports of the Treasurer and Secretary be received and filed, and that the names as recommended by the Board of Direction be stricken from the list of members.

The following gentlemen, reported by the Nominating Committee at the December meeting, were unanimously elected: President (one year), Charles F. Scott; Vice-President (two years), Chester B. Albree; Directors (two years), C. B. Connelly and Charles Hyde; Secretary (one year), Charles W. Ridinger; Treasurer (one year), A. E. Frost.

The address of the retiring President is appended to these minutes.

On motion, the meeting adjourned at 10.20 P. M.

C. W. Ridinger,
Secretary.

REGULAR MEETING.

The two hundred and twenty-first regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's house, 410 Penn Ave., Pittsburg, Pa., Tuesday evening Jan. 21st, 1902, at 10:20 P. M., the newly elected President, Mr. C. F. Scott, being in the chair, and thirty-eight (38) members and visitors present.

The minutes of the preceding meeting were read, amended and approved.

The Board of Direction reported the names of eleven (11) applicants for membership that had been approved, and were to be voted for at the next regular meeting.

The following applicants were then balloted for, and duly elected to membership:

CHARLES M. CLARKE, - -	Patent Attorney, 433 Fifth Ave., Pittsburg, Pa., h., 717 Ivy Street, Pittsburg, Pa.
SAMUEL E. CLARCKSON, -	Construction Engineer, Jones & Laughlins, Ltd., Pittsburg, Pa. h., 329 Lawn Street, Pittsburg, Pa.
OTTO EISENSCHIML, - - -	Chemist, Carrie Furnace, Rankin, Pa.
FRANK IRELAND ELLIS, -	Mechanical Engineer, With Frank-Kneeland Machine Co. Pittsburg, Pa., h., Sixth Street, Aspinwall, Pa.
CURTLAND C. GARDNER, - -	Contracting Engineer, United Eng. and Foundry Co., 54th St., and A. V. R. R., Pittsburg, Pa.
CHARLES H. GARLIC, - -	Mechanical Expert, With Atlantic Refining Co., Pittsburg, Pa., h., 164 Lafayette St., Pittsburg, Pa.
FREDERICK H. N. GERWIG, -	Steam Engineer, Duquesne Steel Works, Duquesne, Pa., h., 507 Franklin Ave., Wilkinsburg, Pa.

WALTER SCHMIDT, - -	Draughtsman, Westinghouse Elec. & Mfg. Co., East Pittsburg, Pa., h., 421 Denniston Ave., Pittsburg, Pa.
DAVID YOUNGS SWATY, -	Civil Engineer, Penn'a Lines West of Pittsburg, Chief Engineer's Office, 1013 Penn Avenue, Pittsburg, Pa.
EDWARD JAMES TAYLOR, -	Civil Mining Engineer, Chief Engineer, Pittsburg Coal Co., Pittsburg, Pa., h., 229 North Craig Street, Pittsburg, Pa.
FRANK B. WARD, - - -	Manager, Pittsburg Office, Niles Tool Works Co., Bement, Miles & Co., Pond Machine Co., 1118 Carnegie Building, Pittsburg, Pa.

On motion of Prof. F. C. Phillips the President was directed to appoint a Reception Committee for the meeting of the American Association for the Advancement of Science, to be held in Pittsburg, June 28, 1902.

The President appointed the following members to act on this Committee:—

Messrs., Charles F. Scott, Chairman, Geo. A. Macbeth, H. W. Fisher, Emil Swensson, Prof. S. M. Kintner, Dr. K. F. Stahl, Jas. M. Camp, Dr. F. C. Phillips, A. G. McKenna, and Jas. O. Handy.

Meeting adjourned at 11:00 o'clock, P. M.

C. W. RIDINGER,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting of the section, was held January 23, 1902, in the rooms of the Society, the Chairman elected, Dr. K. F. Stahl, presiding.

The minutes of the last meeting were read and approved.

On motion, the Chairman appointed a Committee of five, to act in conjunction with the Committee appointed by the Chairman of the Engineers' Society, to devise ways and means of assisting in entertaining the visiting members of the A.S.A.S. & A. Ch. S., which meets in Pittsburg, June 28, 1902.

The following gentlemen were named for that committee:

James M. Camp, Prof. F. C. Phillips, A. G. McKenna, J. O. Handy, Dr. K. F. Stahl.

On motion, the Chairman appointed as a program Committee for ensuing year Messrs. J. M. Camp, A. G. McKenna, and J. O. Handy, also persuant to a motion, a Committee on Chemical literature, Messrs. Craver, Mohr, and Walters.

Dr. Stahl, in a short address, asked for the co-operation of the members of the section, in an endeavor to make the meetings and the work of the year, profitable and interesting, referring also to the interest which should be aroused in all the Chemists of this vicinity, by the approaching meeting of the American Chemical Society.

During the general discussion of interesting chemical phenomona, the Chairman requested that the section make thorough investigation of the cause and extent of the action of sunlight on the absortion of Hydrogen Sulphide by Cadmium Chloride in Ammoniacal Solution as used in the evolution method for Sulphur in iron and steel, the Committee appointed to investigate said action, reporting results corroborating statements of Mr. Walters, at the November meeting.

On motion, the section adjourned at 10 P. M.

CHAS. H. RICH,

Secretary C. S.

PRESIDENT'S ANNUAL ADDRESS.

H. W. FISHER.

Our twentysecond anniversary marks a period of great industrial activity, a condition which is especially gratifying to the engineers, because at such times there are better opportunities for original work, big problems are coming up for solution and a well earned competence is assured.

As a Society we have cause for congratulation at the heathly state of our finances and the excellent papers that have been contributed.

We are, perhaps, justified in the belief that our environment is conducive to the best engineering work, and we know that many of our members have acquired national, and some international, fame. While, therefore, it is reasonable and right that we should be proud of our Society, yet there are two things that we should justly hold in higher esteem, viz:—

1st. The rapid advancement in modern civilization through the various branches of engineering.

2d. The integrity which is of necessity a part of the character of the true engineer.

In his work the engineer must think, design and execute correctly. The consequences of incorrect design or lack of material are far too serious to admit of careless work. This continual attempt at correct thinking, therefore, has a tendency to the building up of a high type of character.

We may therefore feel justly proud of our profession which has not only been the means of giving us the many comforts and luxuries that we now enjoy, but has also enabled us to learn more about nature and the heavenly bodies, and the life sustaining elements, heat and light.

Engineering has become so specialized during the last few decades that it is rather a difficult problem to write an address that will be equally interesting to our greatly diversified engineers. Moreover, an engineer has to be broad indeed who

can write well and correctly on any topic without much previous study. In this rushing age, economy demands that papers or addresses contain data in concrete form and of unquestioned correctness. At the close of a century of unprecedented progress, the mind naturally wonders what we may reasonably expect during the early part of this century which has begun so promisingly.

With these various various ideas in view, your President thought that perhaps the most satisfactory way to obtain correct and interesting data would be to invite correspondence with large manufacturing concerns and the heads of government departments.

With this end in view a number of letters were sent out asking for information regarding new methods of manufacture, large or new types of machines, amounts of materials used, and closing with a request for a few prophetic remarks as to what may be reasonably expected in increased size of machines, new types of machines, etc., during the early part of this century. The responses were liberal and extremely interesting, and as many do not admit of abbreviation it was thought best to present them mostly in full.

Information and data received from various departments of the government:

OFFICE OF THE CHIEF OF ORDNANCE, UNITED STATES ARMY,
WASHINGTON, NOVEMBER 20, 1901.

SIR:

Your letter of the 19th instant, on the subject of the work done by the Ordnance Department, has been referred by the Chief of Ordnance to me for reply.

It is rather difficult to know exactly what limits to give to a question of this nature, as the time within which improvements were made is necessarily a great factor in such cases.

If you request only a knowledge of advances made during the year, the answer could be very easily and definitely made;

but, if it covers a longer period the answer, of course, will also have to cover more ground. In such a case it is thought best to indicate generally the important advances that have been made in the last few years.

With regard to size and destination of manufacturing products in our department, I may say that, as is probably known to you, while the calibers of the guns have changed very little from the old calibers used many years ago, the weights and lengths have changed greatly; for instance, the old 15-inch gun which was used during the war of 1861-1865 carried a solid projectile weighing about 450 pounds, and the gun itself weighed about 22 tons. The present 12-inch rifle is made of steel, weighs about 50 tons, and carries a projectile weighing 1,000 pounds. The same relative advances have been made in all other calibers, 8-inch, 10-inch and those below.

At present the largest gun under manufacture by the department is 16-inches in caliber, weighs 126 tons, its projectile weighs 2,400 pounds, and at a range of 3,500 yards it is calculated to have energy sufficient to pierce from 28 to 30 inches of steel armor. This may be considered to represent the extreme development of guns, so far as the diameter of the bore is concerned.

The tendency now is to maintain the present calibers and increase the velocity of the projectile, thereby increasing the energy and concentrating it more on a given point in order to pierce the modern face-hardened armor.

A new class of guns has also been introduced within the last few years which we call "rapid fire" or "quick fire" guns. These were originally intended for the protection of naval vessels against the attack of torpedo boats. They have been developed so that they are now used not only for this purpose, but also for secondary armament on board ships and against the upper works and lighter armor of the vessels themselves, as they run up to 6-inches in caliber, and some even as high as

8-inches. They are also used in land fortifications for defense against land attack.

Another class of guns which has been developed lately is the automatic gun, which is generally limited to the small calibers and runs up to the one-pounders, and perhaps may go a little beyond this weight. The automatic gun is one which, as its name indicates, fires automatically; that is, after the first discharge of the gun the pressure of the gas acts to open the breech, extract the empty cartridge case, load another cartridge into the chamber, close the breech and fire the cartridge, and this process continues until all the cartridges are exhausted. Some well known types of these guns are the Maxim, Colt, Mauser, and a number of others which need not be mentioned.

In small arms, the same automatic principle has been applied, and lately the automatic pistol has come into vogue, and experiments are now being made with the probability that the troops will, in future be equipped with a pistol firing a number of shots automatically.

In small arms, the caliber has been reduced from the old 50 and 45, which were used in the civil war, and from that date until within a short time ago, to the 30 caliber and below. This reduction in caliber occasioned a number of changes, among them being a larger amount of ammunition to be carried by the individual soldier, on account of the diminished weight of a single round; flatter trajectory of the projectile, owing to its very high velocity, and consequently increased chance of hitting at longer ranges.

The introduction of smokeless powder has given us a ballistic agent which is very much superior to the old black powder in its action, since its gives relatively lower pressures for the same velocity of projectile, or if the pressures are higher within the limits of safety, we can very much increase the velocity of the projectile, because the burning of the powder can be perfectly regulated and the pressures kept up better over the path of the projectile through the bore. This same remark

with regard to smokeless powder applies to the smokeless powder for all guns, including the large ones.

Smokeless powder as originally introduced was not intended to be used particularly on account of its smokelessness—it was only an incidental quality—but because of the fact that high expolsives are necessarily used to obtain a better ballistic agent than the old black powder, and these were smokeless.

With reference to the carriages upon which the seacoast guns are mounted; it is probably known to you that the majority of them in the service are mounted on what is called the "disappearing carriage"; that is, the gun is so mounted that it rises above the parapet for firing, and the energy of the discharge serves to depress the gun below the parapet for loading. This problem, which to any mechanic is a serious one, when we think of the energy and weight to be handled and controlled absolutely, has been successfully worked out by the department and the carriage is now installed in nearly all of our seacoast fortifications; is capable of perfectly controlling the fire of all the modern guns mounted in the fortifications; gives the great advantage of exposing a minimum target to the enemy's fire, maximum protection to the gunners, great facility for loading, and many other advantages which need not be detailed.

The most recent advance in modern field artillery has been the attempt to establish a field carriage without recoil; that is, the field gun is now mounted on a carriage so arranged that it remains fixed in position during firing, and the gun once sighted on a target retains its position and does not require re-sighting during the fire. This problem also, it is believed, has been worked out successfully by the department, and a number of these carriages from foreign manufacturers, and carriages of our own design, are about to be submitted for test, which undoubtedly will improve interesting.

Another very important matter which has recently been developed and settled is the selection, after a long series of

trials, and the adoption of a satisfactory high explosive to be used as a charge in armor piercing projectiles. This matter has been one of great difficulty, as, speaking generally, if a high explosive is so sensitive that it will explode on striking armor, it will generally explode in the gun from shock of discharge, on the other hand, if it is desensitized so that it will not explode in the gun, it will generally not explode with certainty on striking armor. The difficulty then was to get an explosive which would fulfill these conditions. The department has succeeded in accomplishing its object by desensitizing the explosive so that it will not explode in the gun, and by developing a fuse which will detonate the explosive on striking the target, or in passing through it; the fuse being so arranged that it can be exploded at any given time within very narrow limits.

This is considered to be one of the most important modern developments, and it is believed, so far, that no other country has solved the problem to this extent.

It is difficult to say what developments may be expected in the near future in ordnance matters. All the military powers of Europe are constantly studying these problems, and they are also being studied in this country, and Europe is being watched to see if they have any developments which are worth looking into.

As a general rule (if a general rule can be applied to such matters) the evolution of these different war materials goes on along certain lines in time of peace; a war is needed to test the accuracy of many theories, and many materials which have been the product of theory, and therefore wars are always a signal for great revolutions in materials of this nature, and what these revolutions will be no one of course can tell.

I trust the above outline will give you something that is worthy of consideration, and regret that it cannot be made more full, as it is a vast subject, as you understand, and only certain points can be touched upon.

Very respectfully,

L. L. Bruff,

Capt. Ord. Dept., U. S. A.

BUREAU OF ORDNANCE, NAVY DEPARTMENT.

WASHINGTON, D. C. Nov. 29, 1901.

SIR:—

Referring to your letter of the 19th instant, requesting information relative to work accomplished and improvements made under cognizance of this bureau during the past year:

1. As regards the number of guns manufactured, their destination, size, etc., you will find all the information you desire in the Report of the Chief of Bureau of Ordnance.

2. As regards the development of ordnance; a statement of what has been accomplished in any one year would not be satisfactory, as the improvements are not on the same lines each year. A more comprehensive idea of the advancement made can be gained by considering the results of all the improvements made during a period of several years. For this purpose a table is enclosed giving data relative to 6″, 8″ and 12″ guns manufactured in 1891, and corresponding data for guns of the same caliber of the current year. The improvements, generally, are in increased muzzle velocity and rapidity of fire. The increase of muzzle velocity is mainly due to increased length of bore, and the use of smokeless powder. The increased rapidity of fire is mainly due to improvements in mechanisms.

Respectfully

V. O. CHASE,

Acting Chief of Bureau of Ordnance.

Model of	Weight of gun tons.	Weight of projectile pounds.	Muzzle velocity ft. per second.	Muzzle energy foot tons of 1 shot.	Shots per minute	Muzzle energy per minute.	Muzzle energy per minute per ton weight of gun.
				6-inch			
1891	4.82	100	2000	2773	1	2773	575
1901	8.37	100	2900	5838	3.5	20433	2441
				8-inch			
1891	15.2	250	2150	8011	.5	4006	263
1901	18.0	250	2800	13602	1.2	16322	907
				12-inch			
1891	45.1	850	2100	25986	.3	7796	173
1901	52.0	850	2800	46246	.6	27747	533

WAR DEPARTMENT

SIGNAL OFFICE, (TELEGRAPH AND EXAMINING DIVISION.)

WASHINGTON, Dec. 16, 1901.

DEAR SIR:—

Your letter of December 13 has been referred to me by the Chief Signal Officer. In accordance with his request I shall invite your attention to some of the subjects brought out in this year's Annual Report of the Chief Signal Officer, together with several items of interest regarding recent improvements.

The most important advance made by the Signal Corps in the past year is in Cable laying in the Philippines. As you will note from the map at the end of this year's Report (brought up to date) the Philippine government cable system is now very extensive, and with additions contemplated will be unique as a cable network. Practically the whole of this was laid by the U. S. Cable Ship "Burnside" under direct supervision of officers of the Signal Corps. The cable is all rubber cable principally of two kinds—the lighter weighing about 1,800 lbs. per knot, and the larger about 3,500 lbs. per knot. The resistance of the smaller is about 21 ohms per knot, and that of the larger 10 ohms. The insulation resistance is about 1000 megohms per knot at 75 F. This type of cable has given satisfaction. Some of it lies in 1,000 fathoms, its insulation being greatly improved by the pressure and cold at that depth, although there was great doubt expressed regarding the effect of pressure on the rubber by the advocates of gutta percha. But the performance of rubber cable in the Philippines has convinced every one connected with handling it, that for the trying conditions under which it is transported, stored and laid there, it is the best type.

Under the present methods of working the short sections, not exceeding 150 miles in any case, the ordinary open circuit set with polarized relay is found to give good service. A current of 12 milli-amperes is found to suffice, and a speed of 25 words per minute can be attained.

Steps are now being taken to provide for working "through" from Manila to the new Department Headquarters at Cebu. For further details concerning the cable work, etc. I would refer you to pages 15, 16, 17 and 18 and pages 119 to 135 Annual Report. The Signal Corps is charged with the operation of over 3,000 miles of land lines and four hundred and fifty offices in the Philippines.

The extension of the Signal Corps lines of Alaska from St. Michael up the Yukon to Ft. Gibbon and from Valdez up the Copper River Valley—both lines to connect with Ft. Egbert, now the terminal station of the Canadian line to the Klondike—are noteworthy achievements. While most of this line is of galvanized wire on poles, a light unarmored cable is used in some difficult sections. At last reports about 400 miles of line were in operation. (Pages 37 to 45.)

The operation of the 3,418 miles of lines in Cuba is entirely under direction of the Signal Corps. (Appendix No. 6.)

A most interesting chapter of the field work under most novel and trying conditions of the Signal Corps in China is found in the Report—pages 45 to 72.

The difficulties and dangers, the great labor, and the numerous expedients required to carry the line from Taku to Tientsin and from Tientsin to Pekin are worthy of note. The fact that the line reached Pekin thirty hours after the troops, and days before that of any of the other Allies should be noted.

In regard to apparatus: All the land telegraph lines are operated with the ordinary American Morse. Many of the branch lines are being converted into telephone lines in the Philippines. The new Signal Corps telephone, which can be closed up and shipped in its own case, is being introduced, while a new portable field telephone is a model of neatness and compactness. A new field switchboard for camps and small posts has also been designed. The use and development of the vibration system of telegraphy in the Signal Corps "buzzer", has produced some very interesting results. In this instrument

[illegible] WESTERN PENNSYLVANIA

WAR DEPARTMENT

[illegible] TELEGRAPH AND CABLE DIVISION.

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[illegible]

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The [illegible] tirely under direction of [illegible]

A [illegible] interesting [illegible] move and [illegible] found in the Report—[illegible]

The difficulties [illegible] numerous expedients [illegible] [illegible] fact that the [illegible] and [illegible]

In [illegible] operate [illegible] be [illegible] [illegible] Philippines [illegible] close [illegible] a new [illegible] parties [illegible] [illegible]

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the Morse signals are produced by long and short buzzers in the telephone receiver. The wirer has worked these buzzers over twenty miles in Central Luzon, during a rainy period, with bare wire laid on the ground, trees and bushes—and has sent several thousand words per day at that. By using condensers between the buzzers and line they furnish a temporary means of duplexing a telegraph line—as in the phonoplex system.

An instrument, recently introduced, furnishes a simple means of cutting in temporary telephone offices on a telegraph line, where the services of an operator can not be obtained. In wireless telegraphy, experiments have been continued, not so much in attempts at great range, as to find the capabilities of the apparatus in every-day use. The wireless stations in San Francisco Harbor have been worked continuously for over a year. For visual signalling the longest range has been attained with the Signal Corps Portable Searchlight, where searchlight signals have been received for over fifty miles from Manila. Not far behind this in performance is the acetylene lantern, which, in tests at Buffalo, has been read thirty miles. This lantern is an excellent piece of compact and portable apparatus.

The Signal Corps has a testing room at Washington, and shops and apparatus at the Signal Corps Post at Fort Myer, across the river from Washington, where investigations of new apparatus and supplies are constantly going on.

An important branch of scientific work is being developed in the Signal Corps with reference to inspection, testing and installation of the cables, telephones, telegraphs, electric indicators and clocks, and meteorological instruments furnished the Coast Artillery posts in connection with the important and complex fire control communications in the service of the various guns.

Very respectfully,

EDGAR RUSSEL,

Captain Signal Corps, U. S. Army.

DEAR SIR—

Your letter ... been referred to me ...

... the recent ... corn stalks ... fibrous ... be a ... tically wasted.

There are ... plant ... extensive ... is not ... by automobiles ...

The extension ... for pumping ... the engines ... raise ... The lifting ... western L... rice has assumed ... led a number of ... make special study of ... certain machines to ...

Among the directions ... destined to have large development ... works for the reclamation of arid lands in the West, the construction of dikes to reclaim the overflowed and tidal land along the Atlantic and Gulf coasts, terracing and draining to prevent the destructive erosion of hillside farms.

I regret that I do not feel qualified to go further into details in these matters outside of irrigation without some special

the Morse signals are produced by long and short buzzers in the telephone receiver. The wirer has worked these buzzers over twenty miles in Central Luzon, during a rainy period, with bare wire laid on the ground, trees and bushes—and has sent several thousand words per day at that. By using condensers between the buzzers and line they furnish a temporary means of duplexing a telegraph line—as in the phonoplex system.

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Very respectfully,

EDGAR RUSSEL,

Captain Signal Corps, U. S. Army.

UNITED STATES DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS.

WASHINGTON, D. C., Nov. 29, 1901.

DEAR SIR:—

Your letter addressed to the Secretary of Agriculture has been referred to me for attention.

One of the directions in which progress is being made is the recent inventions for utilizing both the outside and pith of corn stalks in the manufacture of building paper and a tough fibrous board for boxes and other purposes. This promises to be a profitable use of a product that until now has been practically wasted.

There are indications that steam power will in time supplant horse power in hauling on country roads, especially in extensive districts devoted to market gardening. Where fuel is not too expensive, the saving in time which can be effected by automobiles is quite an item.

The extension of irrigation has led to a growing demand for pumping machinery to be used for this purpose. Some of the engines now employed on the Hawaiian sugar plantations raise 20,000,000 gallons of water daily to a height of 500 ft. The lifting of water from the bayous and streams of southwestern Louisiana and southeastern Texas for the irrigation of rice has assumed large proportions in the past two years, and led a number of large manufacturers of pumping machinery to make special study of the conditions with a view to designing certain machines to fulfil them.

Among the directions in which agricultural engineering is destined to have large development in the future are irrigation works for the reclamation of arid lands in the West, the construction of dikes to reclaim the overflowed and tidal lands along the Atlantic and Gulf coasts, terracing and draining to prevent the destructive erosion of hillside farms.

I regret that I do not feel qualified to go further into details in these matters outside of irrigation without some special

research which I have not the time to make. Should you desire any further information regarding irrigation development, I shall be pleased to write you again.

Sincerely yours,
ELWOOD MEAD,
Irrigation Expert in Charge.

Information and data received from Ship Building Co.'s:—

NEW YORK SHIP BUILDING COMPANY,

CAMDEN, N. J., NOVEMBER 8, 1901.

DEAR SIR:—

We are in receipt of your favor dated 5 N 01 and note your request for such information as we can give you regarding the ships and engines we have under construction, and we note also the purpose for which you desire this, and it will give us great pleasure to give you such assistance as is within our power.

1st. As to our present contracts:—

Contract No. 1, S. S. "J. M. Guffey" is a ship of the following dimensions:—

309′ 7″	Over all.
300′ 0″	B. PPS.
40′	Beam Moulded.
26′	Depth Moulded to Upper Deck.
5990	Tons Displacement on draft of 22′.

She has engine and other boiler power of 1500 I. H. P. and a required sea speed of 10 knots. This boat was designed originally as a merchant tramp steamer, but before final delivery she was purchased by a second party and is now being converted into an oil tanker.

Contract No. 2: Our Contract No. 2, S. S. "Texan," is a ship of the following dimensions:—

484′ 3″ Over all.
471′ 0″ B. PPS.
57′ 0″ Beam Moulded.
42′ 0″ Depth Moulded to Shelter Deck.
35′ 0″ Depth Moulded to Upper Deck.
16267 Tons Displacement on 27′ draft.

This ship is fitted with twin screw quadruple exp. engines, and the boilers are fitted with a hot air system of forced draft for an indicated H. P. of 3,000 at 10 knots.

Contracts No. 3 and No. 4: Our contracts No. 3 and No. 4 S. S. "Nevadian" and S. S. "Nebraskan," are ships of the following dimensions:—

371′ 6″, Overall.
360′ 0″, B. PPS.
46′ 0″, Beam Moulded.
27′ 2″, Depth moulded to Upper Deck.
34′ 8″, Depth moulded to Shelter Deck.
8267.8 Tons Displacement on draft of 25′.

These boats are fitted with twin screws, triple exp. engines and Scotch Boilers fitted with a hot air system of forced draft, for an indicated H. P. of about 2,500 at 11½ knots.

Contracts Nos. 5 and 6: Our contracts Nos. 5 and 6 are ships of the following dimensions:—

615′ 3″, Over all.
600′ 0″, B. PPS.
65′ 0″, Beam Moulded.
43′ 3″, Depth Moulded to Upper Deck.
51′ 3″, Depth Moulded to Shelter Deck.
26374 Tons Displacement on 33′ 2″ draft.

These ships are fitted with twin screw, quadruple compound engines balanced on the Yarrow,-Schlick,-Tweedy System, and fitted with Lovekin, Tom balance cylinders, with a battery of Scotch Boilers built for a working pressure of 210 pounds per square inch, and fitted with a hot air system of forced draft for an I. H. P. of 12,000, and an estimated sea speed of 15 knots.

Contract Nos. 7 and 8: Our contracts No. 7 and No. 8 ships of the following dimensions:—

505′ 6″,	Over all.
490′ 0″,	B. PPS.
58′ 0″,	Beam Moulded.
35′ 0″,	Depth Moulded to Upper Deck.
43′ 0″,	Depth Moulded to Shelter Deck.
17247	Tons Displacement on 27′ Draft.

These ships are fitted with twin screw triple expansion engines and a battery of Scotch Boilers, built for a working pressure of 200 pounds per square inch, and fitted with a hot air system of forced draft for an I. H. P. of 6,000 and an estimated sea speed of 12 knots. The foregoing eight steamships are being built for American ship owners, and are designed for service both across the Atlantic and Pacific Oceans.

In shipbuilding proper the tendency of the last few years has been toward what we term "extreme dimensions," that is to say that the successful steamships of to-day are of a much greater displacement than was considered possible a few years ago. You are of course, doubtless aware that some of our most modern steamships have already superseded the "Great Eastern" in dimensions, and thanks to the progress made by the Marine Engineer, these boats are beyond question a success; the wisdom of this increase will be readily appreciated when we investigate the quantity of coal consumed per 100 miles of two ships, extremes in dimensions.

A ship, say, of 8,000 tons displacement and another of 26,000 tons displacement are both designed for the same speed; the smaller ship will absorb anywhere from 7 to 8 pounds of coal per 100 ton mile, whereas the latter or larger ship will require something less than 5 pounds of coal per 100 ton mile, ssuming, of course, that the efficiency of the engines in each ship is equal. It is therefore readily understood how economical ships of these increased dimensions are when we consider that

the operating expenses for the personnel of the larger ship will be very little more than that of the smaller.

Another great improvement due to the introduction of these large steamers has been in the re-distribution of the material throughout the structure. That which was originally known as the shelter deck and which was not considered a strength deck is now being transformed into the strength deck of the ship by reason of the heavy material being raised to the top cord.

We would also call your attention to the fact that seven of these eight steamers we are building are being fitted with twin screw machinery, showing the owner's desire to eliminate as far as possible the opportunities for total disablement. It is probable that at the present time they do not fully reap the benefit of this great improvement, but undoubtedly the underwriters will in time see their way clear to make this a consideration when settling the rate of insurance on these ships. It was mentioned above that the engines of Contracts 5 and 6, were being balanced on the Yarrow-Schlick-Tweedy System and the reason for this is that the vertical unbalanced forces tend to produce a series of vibrations throughout the hull, which when coincident with a natural period of vibration of the ship itself, becomes a great element of danger to the structure as well as discomfort to the passengers. It is therefore attempted to so balance the vertical forces of these engines that its effect on the ship's structure will be nil. This system of balancing is in our belief one of the most important items that has tended to make such ships as the "Deutschland" possible, and for high speed ships of comparatively light structure cannot be ignored and should be considered one of the greatest improvements in modern engineering.

As to the future regarding the size of modern engines and steamers we are of the opinion that the size of the individual unit for marine propulsion has been about reached, and that the aggregate power however will be increased by the number of individual units, such for instance as from the twin screw to the

triple screw, and when occasion demands for the triple screw even to the 4-screw engine. We would not be at all surprised to see one or two steamers built within the next few years which would be over or very nearly 800 feet in length. It is doubtful, however, whether it would be advisable to increase beyond this length, as to do so would necessitate the re-construction of the terminals and with a few exceptions the necessary depth and draft of water to maintain structural strength would limit them to but few ports of call.

In the propelling machinery proper we think we might look forward to two very radical changes:—The further development of the multi-tubular or express boiler as a high pressure steam generator, and the adoption of the turbine engine for this class of ship. The adoption of the foregoing would in our opinion be the means of considerably reducing the time between New York and European ports.

Trusting information will be of some service to you, we are,

Very truly yours,

P. P. Newman,

General Superintendent.

UNION IRON WORKS,

San Francisco, Nov. 13, 1901.

Dear Sir:—

Referring to your letter of the 5th inst., addressed to the Union Iron Works, and which has been handed to me for reply, asking if we would mention in brief the capacities and destinations of some of the large marine engines and steamers we have built during the year, and other information that you desire for use in connection with your annual address to the Engineers' Society:

In regard to marine engines that we have built that will go or have gone into operation this year, I might mention those of

the three Torpedo Boat Destroyers, the Paul Jones, Perry and Preble. These are of the usual high speed, light weight, high grade material type, usually built for vessels of that class, and are of 8,500 indicated horse power each set.

We also completed and delivered the Battleship Wisconsin, having triple expansion engines of 12,000 indicated horse power.

We have in the shop at present, and ready to be hoisted on board the Ohio, a set of engines of the four-cylinder type, with 18,000 indicated horse power.

In regard to improved types of marine engines on steamers: There has been no marked improvement in machinery of this class for the past year or two. There has been a betterment in proportion, principally due to the higher grades of material now obtainable for the most important parts of marine engines.

We are just completing one of two sister ships for the American-Hawaiian Steamship Company, which are the largest cargo carrying steamers so far built in the United States. They are intended to carry 11,500 tons dead weight cargo. They have twin screws, and 3,600 horse power. These ships embody all the latest improvements in the cargo type of merchant vessel, and very elaborate provisions have been made for the handling of cargo quickly.

In regard to what is in the future with reference to marine engineering: I do not think that we are to be called upon in the near future to build engines very much, if any, larger than we have been building. There will, no doubt, be an increase in the size of vessel, but that increase is likely to be devoted to the carrying of freight rather than in providing space for engines and boilers. There is a decided reaction from high speed ships apparent amongst the various steamship companies. There will probably be an increase in the size of propelling machinery for war ships. We have two now contracted for the United States government, fitted with 22,000 indicated horse power, and another one of 20,000 indicated horse power.

As to any new types of engines: There will, no doubt, be further experiments made with engines of the turbine type, but it would be difficult to predict what the future of that type of engine is likely to be.

There will, for the next few years, be quite a variety of types of boilers fitted to all kinds of vessels. Whether the experience resulting from attempts to introduce the various types of water tube boilers will result in the production of a new type of boiler that will entirely supercede the cylindrical boiler, is one of the questions that will occupy the minds of those who have a desire to predict what is going to be for the next few years. Those of us, however, who are working out these problems, have little time and not much inclination for speculation as to what is likely to be the result. So far no marked improvement has resulted from the various experiments made with the different types of water tube boilers, and it appears to me that the cylindrical internally fired Scotch boiler is likely to hold its own for some years at least, or until something superior has been devised, of which there does not appear as yet to be an indication. I look for a gradual and steady improvement in marine engineering and shipbuilding, without any new types of engines or boilers coming into general use. This opinion may be considered as perhaps too conservative, but I am reasoning from the slow but steady advance that has been made in the past twenty years or so, and which, I take it, will be the condition of advancement during the next twenty years to come.

Yours very truly,

G. W. Dickie.

NEWPORT NEWS SHIPBUILDING & DRY DOCK COMPANY,

Newport News, Virginia, Nov. 12, 1901.

Dear Sir:—

Referring to your letter of the 4th instant relative to large ship and engine construction work we have turned out during

the present year. We beg to give below a brief statement of this work, in accordance with your request.

Although the year has been an extremely busy one, it has so happened that the actual finished tonnage leaving the yard has not been as large as in previous years when no work was in hand. Two of the last batch of ships for the Southern Pacific Company's "Morgan Line," between New York and New Orleans, have been put on service this year and have at once taken their place with the others of the same line already built by this Company. The completion of this last quartet of ships will swell to twelve the total number of ships of the same type built by this Company for the Southern Pacific Company. These ships are 406 feet long by 46 feet beam by 33 feet 9 inches depth, and have a carrying capacity of approximately 5,000 tons. They are driven by triple expansion engines, 33 in. by 52 in. by 84 in. by 54 in. stroke, supplied with steam by three Scotch boilers carrying 180 pounds pressure. While these ships are not remarkable from the point of view of size, they represent what is probably the highest development of the purely cargo carrier afloat.

Our contribution to the Navy of the United States is the Battleship Illinois, the fastest ship of her class (the other two being the Alabama and Wisconsin) produced. Under a four hours' forced draft speed trial over the government course near Boston, Mass., this ship sustained an average speed of 17,449 knots. On this trial the mean draft was 23 feet, 6 inches, corresponding to a displacement of 11,535 tons, and the horse power required for driving the ship was approximately 12,000. The dimensions of the Illinois are, length 368 feet between perpendiculars, beam extreme 72 feet, 2½ inches, normal draft 23 feet, 6 inches, corresponding displacement 11,535 tons.

Before the end of the year, or shortly after the opening of the new year, we hope to deliver to the Pacific Mail Steamship Co. one of the two large ships now under construction for that line. These ships, the Korea and Siberia, are the largest ships

yet launched from any yard in America, the dimensions being 572 feet over all by 63 feet beam by 40 feet depth. These ships, designed, to trade between San Francisco and Hongkong, with several Japanese ports as ports of call, will have a carrying capacity of 10,000 tons and are expected to show a sea speed of 18 knots, placing them ahead of anything afloat on the Pacific Ocean at the present time. The motive power will be furnished by two engines, each driving a separate screw, the engine being quadruple, with cylinders 35 in. by 50 in. by 70 in. by 100 in. by 66 stroke.

While we have nothing new to describe in the way of a new engine, improvements are constantly being made in details of design and adaptability of different materials.

It is along the line of detail improvements that we chiefly look for future achievements. Among the factors to be reckoned with in future progress, however, must be included the possibility of oil fuel in place of coal. With the vast amount of oil now flowing in different parts of the country, it appears to us extremely probable that a furnace adapted to burning oil may reasonably be expected. Another development concerned strictly with the propelling of the ship may be found in the increased rotative speed of the propellers and the larger number of propellers mounted on the shaft, whether that shaft be driven by the ordinary reciprocating steam engine or at extremely high speeds by some form of steam turbine.

We shall be very glad to have you send us a copy of the January proceedings of the Engineers' Society of Western Pennsylvania, as you kindly offer to do.

Yours very truly,

W. A. Post,

General Superintendent.

THE WILLIAM CRAMP & SONS SHIP & ENGINE BUILDING CO.

OFFICE, BEACH AND BALL STREETS,

PHILADELPHIA, DEC. 16, 1901.

DEAR SIR:—

We have received your letter of the 16th instant, asking for information as to our most important manufactured product during the past year—1901—and what lines of improvement in manufacture or product have been inaugurated here, etc.

In response we would say that our output during the year has been:

The completion of the Imperial Russian battleship "Retvizan" 12,800 tons displacement, 18,000 indicated horse power and 18 knots speed.

The Imperial Russian protected cruiser "Variag," of 6,500 tons displacement, 18000 indicated horse power, and 23½ knots speed.

Work has also progressed as rapidly as the delay in delivering the armor would permit upon the U. S. S. Battleship "Maine," of 12,500 tons displacement, estimated horse power of about 17,000 and guaranteed to make 18 knots speed in a four hours' trial.

Work has been commenced upon the U. S. S. armored cruisers "Colorado" and "Pennsylvania," 13,800 tons displacement, 23,000 indicated horse power (estimated), and guaranteed to develop 22 knots speed in a four hour's trial.

The construction of a protected cruiser of 3,300 tons displacement, 12,000 indicated horse power, and 22 knots speed for the Imperial Ottoman government has been commenced.

During the year we have completed and delivered to their owners:

The twin screw steamships "Esperanza" and "Monterey," of 5,000 tons gross register, for the New York and Cuba Mail Steamship Company.

The single screw steamships "Apache" and "Arapahoe," of 3,350 tons gross register each, for the Clyde Line.

We have begun the construction of a tank steamer to carry 5,000 tons dead weight, or in other words, 1,500,000 gallons of oil.

Work has progressed upon the large passenger steamships "Kroonland" and "Findland" for the International Navigation Co., 12,500 tons gross register each, and 10,000 indicated horse power each, these vessels being now nearly ready to launch.

We have also built during the year a steel pontoon for a new floating derrick under construction by the government for use at the New York Navy Yard; and a caisson to be used for the new Navy dry-dock at Boston.

We have continued the manufacture of the important hydraulic plant for the various water power systems at Niagara Falls; also the construction of a powerful hoisting plant for the Calumet and Hecla Mining Co., besides a great volume and variety of smaller engineering work, which need not in this connection be particularized.

With regard to improvements in plans and methods, we have during the year 1901 completed the installation of our pneumatic power system by means of which nearly all riveting, caulking, chipping, boring and portable drilling is now carried on, the amount of hand work employed in these directions being now reduced to a minimum.

We have installed and have put in operation three overhead travelling cranes or gantries, each of which serves two building slips

We have completed and put in operation a new machine shop, which is among the largest and best appointed in the world, being supplied throughout with new tools, all of which are operated by electric motor-power.

Most of these operations were begun before this year, but as they have all been completed and brought into successful use during the year, we think they should be included as part of its operations.

On the whole, it may be said that the enlargements and improvements above referred to have nearly, if not quite, doubled the capacity of the plant as it was three years ago.

Very truly yours,
CHAS. T. TAYLOR,
Secretary and Treasurer.

Information and data received from Manufacturers of Engines:

ALLIS-CHALMERS CO.,

MILWAUKEE, WIS., November 14th, 1901.

DEAR SIR:—

In reply to your favor of October 31st, we may mention the following as some of the large installations which we have sent out during the last year, the ones selected being those which we think would be of most interest to your hearers:—

Two engines of the 3 cylinder compound type, each of 2500 K. W. capacity, for the City of Glasgow. It is interesting to know that in spite of the bitter opposition by the British Press, the Glasgow authorities were exceedingly anxious, after the receipt of the first two, for us to send them two more. The order, however, was declined on account of time of delivery. We have sent one engine of 1600 K. W. capacity, vertical compound, to Sydney, N. S. W. for the Government tramways there. To Southern Russia—two large steeple compound vertical blowing engines, each with two 87 in. air cylinders. A duplicate went to Birmingham, England. These engines are both of the standard type used extensive in the iron districts of this country, and of which we have furnished during the past year, in the Pittsburg district, in the neighborhood of thirty, with air cylinders varying from 87 in. to 100 in. These are distributed between Jones & Laughlins, Carnegie, Riverside Iron Works, National Steel Co. at Bellaire, Newcastle and Mingo Junction.

For Street Railway lines the most notable order was one for eight engines for the Manhattan Elevated Railway Co. These are the double combined horizontal and vertical type, each with two high pressure cylinders 44 in. diameter, low pressure cylinders 88 in. diameter, all by 60 in. stroke. The horse power at best load is 8000, and a maximum of 12,000 per unit is guaranteed. This has recently been followed by an order for six more of the same type for the new sub-way of New York City.

Another new departure is the Worcester blooming mill engine. This is similar to one-half of the Manhattan type engine. There is a horizontal and a vertical engine, each with a 44 in. x 60 in. cylinder, connected to the same crank pin. This leaves room for the valve gear at one side, and leaves one end of the shaft entirely free for direct connection to the rolls. It is pronounced by everyone who has seen it, the most successful engine for this class of work that was ever built. We are building a second one, which, however, will be compound, 44 in. x 78 in. x 60 in., for the Carnegie people.

As to prophecy in regard to size of engines, our experience seems to indicate that with 2500 H. P. to the cylinder, the limit for reciprocating engines has been pretty nearly reached. This gives 5000 H. P. to the ordinary cross-compound engine, or 10,000 H. P. to the engines of the Manhattan type. It is doubtful whether this will be much exceeded, if at all.

Regarding the new types, it is perhaps idle to prophesy. We are showing our faith in a continued demand for the Corliss type by spending something like three million dollars on a plant which will cover a good part of 100 acres of ground, to care for our present business in this line of work, and there is room and provision made for the extension which we believe will be required.

This shows our faith that there will not be any immediate change, to say the least, in the type of engine used in our large industries. Yours truly,

EDWIN REYNOLDS, Chief Engineer.

THE WESTINGHOUSE MACHINE COMPANY,

January 10th, 1902.

DEAR SIR:—

Answering your favor of January 6th, I will endeavor to give you a short statement of the notable things we have been doing during the past year. We have built and erected during the past year, three distinct types of very large steam engine units, all for the purpose of driving electric generators, and all of them located in eastern cities of this country.

One of these units is of the following description: The high pressure cylinder is 46 in. diameter, the low-pressure cylinder 86 in. diameter, stroke 60 in., revolutions 75 per minute. This engine is fitted with Corliss valve gear throughout, and operates to drive a 2850 K.W. A.C. generator, running in multiple with other units in the same station as well as with engines in other sub-stations of the same Company at remote distances. I enclose herewith a small photograph showing this engine, in fair detail, which will enable you to comprehend something of its general character. The shaft of this engine is probably the largest speciment of its kind ever brought to Pittsburg, it was forged by the Bethlehem Steel Co., South Bethlehem, Pa., from a fluid compressed, open hearth, steel ingot. Forging was done by hydraulic press, and the shaft was hollow forged, that is to say, the ingot was first bored out along axis, by a process which removes the unsound metal at the core or heart of the ingot; a mandril was introduced into this hole after the ingot was heated, and the hydraulic press thus had to penetrate a reduced mass of metal. The forging of a shaft by this means is more dependable and more reliable than by the old method. The shaft was shipped rough-machined from Bethlehem to Pittsburg, and in our lathes we finished the machine work, making all the fits, cutting the keyseats, and making it ready to go into the engine. The flywheel of this engine is somewhat of a novelty, being made up of steel castings, as respects the arms and the rim; the hub sections were

made of air furnace cast iron, having a strength some 50% higher than ordinary cupola metal. The total weight of this immense wheel, which is 28 ft. in diameter is 340,000 pounds. Its bore, that is to say, the diameter of the shaft where it fits, is 39 in. The engine is provided with reheating receiver, in which the steam exhausted by the high pressure cylinder, and on its way to the low-pressure, is first drained and then slightly superheated by passing through tubes surrounded by live steam. This engine runs regularly with condenser, and has developed as high as 6,000 HP per unit. We have two of these units now in active service in Brooklyn, N. Y. Total weight of this engine is about 1,100,000 pounds. The bedplates of each side weight 86,000 pounds each.

The second type of engine to which we have referred, is very similar to the first engine, except that in this case, the high-pressure cylinders are equipped with four poppet valves, instead of the Corliss valves. The motive in making this change in design was to permit the use of superheated steam, which is becoming more or less popular, and which has certain theoretical advantages favoring low steam consumption. The general style and appearance of the engine is otherwise very similar to that shown in the photograph. We are building and have almost completed the erection of two such units as this for a large elevated railway company in Boston.

The third type of engine referred to is of quite different construction. This engine has three cylinders and three cranks, in fact it might be regarded as three separate engines set side by side on a common bedplate. The cranks are divided at irregular intervals, approximating, but not quite, 120″ apart, so as to produce the most even turning movement, and the most regular speed of revolution. The high-pressure cylinder in this instance is 43½″ diameter. The engine has two low-pressure cylinders, each 75½″ diameter, placed on either side of the high-pressure cylinder above referred to. The stroke of the three engines is 60″; revolutions, 75 per minute. This engine

is equipped with poppet valves for its high-pressure cylinder, for the same reasons above mentioned, namely, superheated steam; while the low-pressure cylinders are equipped with Corliss valves, after the usual fashion. This engine is run condensing, with 175 pounds gage pressure, and has developed as high as 9,000 IHP per unit. We have two such engines as this now in regular service, and six others exactly similar, in various stages of completion in our works and in the large power house. The power house in which these latter engines are located is at 38th and 39th Sts., East River, New York City. We are, as you see, building among the largest steam engines ever attempted. The boiler pressures of to-day are enormously greater than they were a few years ago, and the present requirements call for greater strength of design, massiveness, and substantial construction. The weight of the last named engine is approximately 1,600,000 pounds per unit.

As to whether larger engines will be employed in the near future, it is hard to say. Presumably the march of progress will go on, and engines still more immense in size will be called for in the next decade.

We are prepared to keep up with the procession, and are willing to build as large an engine as any other concern in the world can safely undertake. The use of A. C. generators, operating in mutiple, has a tendency to incline designing engineers to very large unit sizes, so as to reduce the number of units which must run in multiple to the fewest possible.

We are also building the very high speed engine known as the turbine engine. The past year has seen the installation of the largest steam turbine ever built for stationary purposes. This engine has developed as high as 3,000 HP, runs at a speed of 1,200 R. P. M., and has attracted great attention among steam engineers during the past year. The engine is now in operation in the city of Hartford, Conn., and runs with superheated steam of high pressure, exhausting into vacuum. We are now at work on plans for turbine engine of double this size,

All of these engines have our positive inlet and automatic outlet gridiron air valves.

We also furnished for the new works of the Union Steel Co., Donora, Pa., a horizontal double tamdem compound Porter-Allen engine, having two high pressure steam cylinders 38″ diameter, two low pressure steam cylinders 75″ diameter by 60″ stroke, for transmitting power through a rope wheel 13 ft. face, weighing 225,000 lbs., and also coupled direct by return crank on one side. The crank shaft for this engine weighed 125,000 lbs.

The engine will develop about 9,000 H.P. maximum. We furnished this same company with two smaller cross compound engines, and engines for their electric power station.

We also furnished to the Colorado Fuel and Iron Co. a horizontal tandem compound Porter-Allen engine, 40″ and 75″ x 60″, which will couple direct to mill, and has a fly-wheel weighing 180,000 lbs., made in two pieces.

We have also built this year a compound reversing engine for a slabbing mill, the first of its type produced in this country. It drives through steel gears with cut teeth, and mounted on end of bed plate. A pair of simple reversing engines are included with the outfit for driving the vertical rolls. This engine weighs 1,250,000 lbs.

In addition we have done a large volume of business of ordinary character. We only refer above to the large examples.

Hoping this furnishes the information you will need for your address to the Engineers' Society of Western Pennsylvania, and that you will find it useful to you, we remain,

Very truly yours,

JAS. H. MALONEY,

Secretary.

Information and data received regarding Pumping Machinery:—

P. H. & F. M. ROOTS CO.

CONNERSVILLE, IND., Dec. 26, 1901.

DEAR SIR:—

Your letter of the 7th inst. was received during my absence from home.

Beg to say that, as far as our pumps are concerned, we have not fully developed them for the different purposes they will be used in the future and could only give you a limited amount of information in regard to them.

We have a large pump installed at the sugar plantation of Schmidt & Zigler, New Orleans, which is used for drainage purposes. This pump is working under a head of from nine to ten feet, is handling about 35,000 gallons per minute, and is far more economical than a centrifugal pump, under the same head, handling the same quantity of water. Our pumps are positive in their action, just as a reciprocating pump is. They require no priming or foot valves.

We are now building two pumps for the Jones & Laughlins Co., Pittsburg, to be used for handling circulating water for condensers. These pumps are to have capacity of 20,000 gallons per minute.

We are about ready to ship a pump to the Illinois Steel Co., So. Chicago, having capacity of 11,500 gallons per minute, and capable of working against a head of 150 pounds.

In regard to gears on these pumps, beg to say they are made of what we call semi-steel—that is, of a first-class quality of Bessemer iron, with a mixture of steel to toughen it, and for 100 pounds, the gears we have on these machines will be amply heavy.

Yours truly,

E. D. JOHNSTON,

Pres. and Gen. Mgr.

ALLIS-CHALMERS CO.

MILWAUKEE, WIS., Dec. 11, 1901.

DEAR SIR:—

Replying to your favor of December 7th, regarding large pumping engines for irrigation purposes, we are glad to know that you also are acquainted with and appreciate the very valuable work which Mr. Mead is so quietly carrying forward. We are especially interested in it because we know Mr. Mead personally, and know of his absolute integrity, and that the work outlined by him will certainly result in very great benefit to our western states, and will be absolutely free from even a suspicion of jobbery, which we think very rightly attaches to a great deal of the irrigation legislation which is most clamorously advocated.

We have made a specialty of large pumps for similar classes of work. We have at New Orleans for the draining of the city, 6 oı 8 units of 250 cubic feet per second capacity each when working against a 10 ft. head. These are electrically driven, and give a duty of about 55 million foot pounds per thousand pounds of dry steam. This includes pump, motor, transmission, generator and engine losses. The equivalent duty for a direct steam driven pump would be between 90 and 100 million.

We have at Boston 9 pumps lifting water and sewage against a head of about 19 feet. These pumps are from 75 to 100 cubic feet capacity per second, and give a duty of over 95 million foot pounds per 100 pounds of coal without deductions of any kind. These pumps are all centrifugal.

We are under contract to furnish a plant valued at about $300,000 with this type of pump for handling the sewage and storm water for the City of Washington, besides numerous smaller contracts at various places.

We have also made a specialty of screw pumps, to be installed where the lifts were moderate and the quantity of water to be handled was great. The largest of these is installed at Milwaukee, and has a capacity of about 600 cubic feet per second

against a head of 3 or 4 feet. We also have half a dozen of these pumps, each of 250 cubic feet per second capacity, installed at New Orleans for raising storm water, the head varying from nothing up to 5 or 6 feet. These pumps also give a duty of upwards of 90 million. The success of this type of pump where large quantities of water are to be handled, has led to their being specified in a number of recent installations, and about the date of the delivery of your lecture two will be contracted for delivering lake water to flush the south branch of the Chicago river, each of which will have a capacity at normal speed of about 700 cubic feet per second against a head of 7 feet.

We hardly feel like making any prophetic remarks, further than to say that for a number of years we have been building machinery of this class giving an efficiency of practically double that which is usually credited to pumps of this nature. This is just beginning to be realized in the engineering world, and perhaps the only prophecy that we would care to make is that there is a prospect of a considerable demand for high duty units of this type.

Yours truly,

EDWIN REYNOLDS,

Chief Engineer.

Information and data regarding Bridge Building:—

AMERICAN BRIDGE CO.,

PITTSBURG DIVISION,

JAN. 8th, 1902.

DEAR SIR:—

In reply to yours of the 6th inst., asking for information in regard to bridge work, we give you the following notes:

Probably the heaviest double track through truss span erected to date, is the span of the Union R. R. at Rankin, Pa., connecting the Carrie Furnaces with the Homestead Steel Works of the Carnegie Steel Co., which weighs 2,500 tons, and with a

metal flooring for the hot metal track 300 tons additional, making total weight of 2,800 tons. This was completed during the year 1901.

Our company also has a contract for the double track cantilever bridge over the Monongahela River for the entrance of the Wabash R. R. into Pittsburg. The channel span will be 860′ and will require 14″ eye-bars, with probably 36″ heads, which are in excess of anything that has been manufactured in the past.

We enclose a newspaper clipping in reference to this work which may have escaped your notice.

One of the old time railroad bridges will be replaced the coming year, by a new structure, viz.—the bridge No. 1 over the Allegheny River for the P. F. W. & C. Ry. This structure will have two tracks on the upper deck and two on the lower, which makes it one of special design.

Another one of the old time bridges which will be displaced, will be the bridge for the P. C. C. & St. L. over the Monongahela River at Pittsburg, which has cast iron end posts and top chord, which will be replaced by the new modern steel structure.

These are the most prominent engineering works to which I can call your attention, that are in process of execution at the present time.

Yours truly,
JAMES K. LYONS,
Assistant Division Engineer.

Information and data regarding the manufacture of Glass:

MACBETH-EVANS GLASS CO.

DEAR SIR:— DEC. 4th, 1901.

As to changes in the glass business in the way of improved methods of manufacture and quality, it may be said there are some striking circumstances in its development.

So far, in the window glass making, the sole improvement has been in the use of very large tanks which it might be safe to say economize fuel at least 50%. Outside of this at the present time there is no difference in the process of blowing it into large cylinders, as has been the custom for many years.

As to pressed glass, under which name we designate what is known in commerce as "table-ware," there has not been much if any change, except as dictated by skilled mechanics, but the improvement has been steady and gradual in the last twenty years, both in quality and design, although it is to be noted there is some improvement contemplated which will make glass dishes all but equal to the finest cut ware.

In bottles and such articles as fruit jars a complete revolution has taken place, and the manufacture of fruit jars is an instance of the trend of many articles. Formerly these articles were blown in a mould by the breath of a workman, the man receiving about $4.50 per day for this work. Almost the entire output now is made by machinery, and the saving has been very great in every respect. There is no blowing by the workman—it is done by compressed air automatically, and, whereas, these goods sold twenty-five years ago for $16.00 per gross, they have now reached as low a price as $3.00 per gross, but a much better article. Formerly the articles coming from the mould required a second process to complete, but now they come from the mould complete, finished better and with a uniform quantity of glass in each jar. The workman in place of receiving $4.50 per day, makes $6.00.

The consumption of this article is about 700,000 gross per annum, which will show the enormous saving to the public on this now necessary article. Almost everybody wishes to preserve the various fruits in which the country is abundant at one time of year, and this makes it within the reach of all, as a purchaser now-a-days can go to almost any grocer and get a dozen jars nicely put up in a wood box for 25 or 30 cents, whereas before they would have cost $1.50.

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[illegible] of bottles are now [illegible] by machinery [illegible], so that it might [illegible] these two branches [illegible] and the consumption increased to [illegible] make the workmen as much in demand as

[illegible] made its appearance, though as yet [illegible] the Owens Blowing Machine, and [illegible] have somewhat the same ef[illegible] more designed for combining [illegible] the impossibility of turning [illegible] designed to make, it will [illegible] as indicated in the [illegible] successful apparatus having [illegible] of the hu[illegible] However this ma[illegible] articles, so far as [illegible] and is nearly [illegible] The man who [illegible] the article in the [illegible] carried away *from* [illegible] are carried *to* [illegible] work, but the accurate [illegible] great success and a great [illegible] Of course it has met with [illegible] the workmen, although by [illegible] more money at a less expenditure of [illegible] expenditure of brain.

[illegible] accuracy of the goods made in this [illegible] can be done in a very large number [illegible] consumption. It is operated by

electric power, and not connected with anything except [illegible] wire.

A word might be said in regard to the manufacture of artistic glass, and by artistic glass we mean [illegible] and ornament purely. It may be [illegible] has not been very prominent [illegible] nature of the commodities manufactured [illegible] center like we have. Most of our [illegible] nature of steel and iron—heavy an[illegible] masses, and it seems it has not been [illegible] in either brass, iron or glass.

There has been among us a [illegible] gard to matters of *design*. We have [illegible] it, but if we embrace the movement [illegible] might be said that the most artistic glass has been [illegible] the United States in the past few years ever [illegible] peculiar combination of color and the [illegible] advance of anything ever attempted [illegible] fany glass. Our own manufacturers [illegible] glass has been able to call in the aid of [illegible] the establishments became larger, to great [illegible] ness and transparency, and there is a better [illegible] ever before.

It impossible to give statistics of the [illegible] of the different kinds of glass manufactured. The [illegible] of our largest manufacturing [illegible] factories are scattered in many places [illegible] arate the different articles made, either as to [illegible] The quantity exported is also unknown, as well as the [illegible] imported, and statements as to this are [illegible] lump sum embracing the whole United States.

GEO. A. MACBETH.

This is a case in which it is perfectly evident that lower price brings greater consumption—due to the advent of machinery, which entirely superseded the old process, and to which the workmen were extremely hostile—has not only been a benefit to the workman but the entire community.

Most all kinds of bottles are now being made by machinery with a similar result, so that it might be said these two branches are entirely revolutionized, and the consumption increased to such an extent as to make the workmen as much in demand as ever.

Another machine has made its appearance, though as yet in its early stages, namely, the Owens Blowing Machine, and while this machine is supposed to have somewhat the same effect, it is hardly likely, as it is more designed for combining quality with quantity; and from the impossibility of turning out the finished article which it is designed to make, it will probably not make the complete revolution as indicated in the fruit-jar machine. It is a perfectly successful apparatus having much more speed than the ordinary blowing by force of the human lungs, as there is none of this work to do. However this machine is noted for turning out perfectly finished articles, so far as smoothness and accurancy of shape are concerned, and is nearly unlimited in the variety of articles it will make. The man who takes the place of the blower simply places the article in the machine, when it is turned and blown and carried away *from* him, while the empty moulds in their revolution are carried *to* him. This cuts off two-thirds of the work, but the accurate regulation of air pressure in this is a great success and a great improvement over the human lungs. Of course it has met with the utmost hostility on the part of the workmen, although by this process they can earn more money at a less expenditure of muscle and not much expenditure of brain.

The clearness and accuracy of the goods made in this machine are marvels of what can be done in a very large number of articles of almost universal consumption. It is operated by

electric power, and not connected, with anything except by the wire.

A word might be said in regard to the manufacture of artistic glass, and by artistic glass we mean articles of luxury and ornament purely. It may be truthfully said that Pittsburg has not been very prominent in this field, possibly owing to the nature of the commodities manufactured in a coal-producing center like we have. Most of our commodities partake of the nature of steel and iron—heavy and rough—meant for the masses, and it seems it has not been conducive to the finer arts in either brass, iron or glass.

There has been among us a deficiency in education in regard to matters of *design*. We have not had much to promote it, but if we embrace the movement in the country at large, it might be said that the most artistic glass has been produced in the United States in the past few years ever known. The peculiar combination of color and the chemistry of it are far in advance of anything ever attempted before. (I refer to the Tiffany glass.) Our own manufacturers of clear and colored glass has been able to call in the aid of chemistry more and more as the establishments became larger, to great benefit in the clearness and transparency, and there is a better use of chemicals than ever before.

It impossible to give statistics of the quantity or amount of the different kinds of glass manufactured. The headquarters of our largest manufacturing concerns are in Pittsburg, but the factories are scattered in many places and it is difficult to separate the different articles made, either as to quantity or value. The quantity exported is also unknown, as well as the quantity imported, and statements as to this are only to be told in the lump sum embracing the whole United States.

GEO. A. MACBETH.

advantage of varying the voltage at each sub-station to accommodate the immediate district to which it supplies power.

This double current generator also has the advantage of being able to use all its power either in the vicinity of the station or in the outlying districts which it is supplying, or any portion of its current in this way, so that as the leak of the load on the station shifts from one part of the system to another, the current generated by this machine can be transmitted to whatever part of the system it is required.

This machine is the most flexible unit which can be used by companies supplying current to thickly populated districts, where the load on a station is very great and economy of space and operation is required.

I recently wrote you giving some information in regard to 2,500 KW double current generator in Chicago. There is one point which I failed to mention, namely, that this machine is the largest of this type which has ever been built.

The MP-36-2700-75, 575 v. generator installed at Lincoln Wharf Power Station of the Boston Elevated R. R. is the largest direct current railway generator in the world. Although its normal capacity is but 2,700 KW, or 4,700 amperes, at 575 volts, it has an overload capacity of 50% for two hours and of 100% for ten minutes, representing at normal load 3,600 electrical horsepower output, 5,400 HP at 50% overload, and 7,200 HP at 100% overload. These are not mere theoretical values, as the machine has been successfully tested and demonstrated these ratings.

The net weight of the machine is 320,000 lbs., of the armature and commutator 120,000 lbs.; of the copper alone in the machine 30,000 lbs., or 15 tons.

Diameter of the armature is 21′ 8″.

Diameter of the magnet frame 29′ 3″.

Length of the machine parallel to the shaft 5′.

Space required on account of moving magnet frame to uncover armature for repairs, etc., 7′ 8″.

The special features of construction are as follows:—

On account of the large diameter, it was impossible to transport the magnet frame in semi-circular sections, as is customary, and hence it had to be designed in six sections, the top sixth fitting like the keystone of an arch.

The armature had to be built up in place; photographs 12,462, 12,460, and 12,459 showing the progress of this work.

In order to facilitate the moving of the magnet frame, a special roller carriage was designed, so arranged that the weight of the machine can be lowered on the same, or removed by one man. Photographs 12,462 and 12,460 show the special tubular construction of the armature spider, and also the internal fan arrangement for efficiently ventilating the armature.

The commutator is mounted from the armature spider, instead of the armature hub, in order to economize material and facilitate inspection and cleaning.

In addition, I would call your attention to article and pictures in Steam Engineering, No. 2, volume No. 3, issued Oct. 15, 1901. The advantages of a large set of this sort have already been pointed out in Mr. Tremper's note of December 9, that is, economy in attendance, steam consumption, oil, supplies, and also in floor room.

THE WESTINGHOUSE COMPANIES—PUBLISHING DEPARTMENT.

November 29, 1901.

DEAR SIR: —

We have your letter of November 21st asking for information in regard to machines of large capacity built by this Company during the last year. We are able to inform you that we have made a record in the building of large machines last year.

The 5,000 KW alternators, a number of which we are just now completing for the Manhattan Elevated Railway Company, of New York City, are the largest machines of this kind ever

built. We have prepared a descriptive article upon these generators which we intend sending out to the technical press within a few days. When we do so will be glad to send you a copy, from which you will be able to get further information in regard to these machines.

The Westinghouse Machine Company has furnished eight 6,000 HP cross-compound engines to the New York Edison Company (which has been merged into the New York Gas, Electric Light, Heat and Power Co.,) and you will find a full description of them in the *Electrical World* of May 25th.

We are also furnishing some rotary converters for the Manhattan Elevated Railway of 1,500 KW each. These are the largest rotary converters ever projected.

At the present time we are building some static transformers for the Montreal & St. Lawrence Light & Power Company. These are to be of 2,750 KW each. We are not prepared to give out any detailed information about them as yet.

One of the developments of the past year which you might wish to incorporate in your address is the "Nernst Lamp." You will find this quite fully described by Mr. A. J. Wurts in his paper read before last summer's meeting of the American Institute of Electrical Engineers. The Nernst Lamp Company, Pittsburg, Pa., will be glad to send you a copy of this paper.

We are building 5,000 HP generators for the St. Lawrence Power Company, and these will be installed in their great plant at Massena, N. Y. Figure X illustrates these.

The alternators mentioned above for the Manhattan Elevated Railway are of the same type as those to be furnished by us for the Rapid Transit Railway, of New York City.

It may interest you to know that five mammoth plants in New York City will aggregate, when completed, nearly half a million horse power. The great uses of mechanical power on Manhattan Island is, we believe, unique as a sociological and historical fact, and you may find it interesting enough to be

alluded to in your presidential address. We are enclosing you an article which we have recently prepared upon this subject, and from which you are welcome to take as much as you wish. It has not as yet been published.

We are not inclined to enter the field of prophesy in our official capacity, but following out the line indicated in the enclosed article you may be able to forecast the conditions of society when the world in general has reached a development corresponding to that of New York City.

If you wish to get photographs for illustrating any of the subjects we have mentioned above, do not hesitate to call upon us for them.

Hoping what we have said may be of some value to you, and asking you to write further in case there is anything else we can do for you, we are,

Yours truly,

GEORGE A. GIBSON.

L. B. STILLWELL, CONSULTING ELEC. ENGINEER.

January 9th, 1902.

DEAR MR. FISHER,

Replying to your letter of January 7th, would say that the Manhattan Railway Company has contracted with the Allis-Chalmers Company for eight engines and with the Westinghouse Elec. & Mfg. Co., for a corresponding number of alternators. The rated output of each alternator is 5,000 KW, but each is capable of delivering, for a period of two hours, 7,500 KW, with a rise of temperature not exceeding 55°C. Each engine at most economical cutoff will develop about 7,500 HP, and is capable of delivering power exceeding that amount by about 50%. It is expected that seven generating units will suffice to operate the system of the Manhattan Railway Company under conditions of maximum load now contemplated. The multiple unit system of the General Electric Company will be used in

operating the trains. Four cars out of each six car train will be equipped with two motors each, the nominal rating of the motors being 125 HP each. I enclose herewith a printed statement explaining this subject in some detail.

The Rapid Transit Subway Construction Company at the present time has contracted for six units similar to those ordered by the Manhattan Company. These six units will suffice to operate the system of the Rapid Transit Company under the schedule which we hope to put into effect, January 1st, 1904. The power plant of this Company, as also that of the Manhattan Company, is capable of extension by installation of additional units.

Prophecy is somewhat dangerous in this field of work, but I am inclined to believe that the next step in the evolution of steam driven electric plants of large size will be in the direction of steam turbines rather than in the use of larger alternator and engine units. In cases where the alternators are driven by hydraulic turbines, as at Niagara, there is no reason why larger units may not be used, and in fact the use of 7,500 KW units for the new plant of the Niagara Falls Power Company on the Canadian side of the river is practically determined.

Very truly yours,

L. B. STILLWELL.

STANLEY ELECTRIC COMPANY,

PITTSFIELD, MASS.

The above company did not send any communication supplying data referring to their work, but referred to the July and October numbers of the *Journal of Electricity, Power and Gas*, and also to volume 46 number 40 of *Engineering News*. From these the writer has culled a few interesting points.

Bay County's Power Company, San Francisco, have the longest power transmission line in the world. The length of this line is about 150 miles, and in the next year or two it will

probably be increased to 214 miles. The power is generated at around Colgate from the waters of the Yuba river. The present E. M. F. is 40,000 volts but this will be increased to 50,000 and perhaps 60,000 or 70,000 volts. The company is delivering or just about to deliver 17,000 HP, and this may be increased to 40,000 HP. The head of water on all 800 feet. The total amount of transmission line used exceeds 3,000 miles. Power is supplied for mining purposes, electric lighting, and various manufactories, and the extent of ground covered is very considerable.

The power house at Colgate contains two 2,000 KW, three 900 KW, and one 750 KW Stanley generators which are directly connected to the water wheel. They are 3 phaze, 60 cycle, 2,400 volt inductor machines. The power houses voltages are increased by step-up transformers to 40,000 volts on the transmission lines. Said voltage is reduced as desired by step-down transformers at the other end of said transmission lines.

Information and data regarding the manufacture of steel and iron:—

CARNEGIE STEEL COMPANY,

JAN. 14, 1902.

DEAR SIR:—

In reply to your letter to our Mr. W. E. Corey, asking for data to be used in an address before the Engineers Society of Western Pennsylvania.

It is a rather difficult matter for us to give you any information that would be of decided interest, but trust the following general items will be of some service:

Last year the Carnegie Steel Company produced 2,300,000 tons of pig iron; 3,500,000 tons of steel ingots, and about 2¼ million rails in number, aggregating about 700,000 tons.

Two notable improvements in steel manufacture are the Kennedy-Morrison process for rolling rails, copy of which we enclose herewith, and the Monell open hearth process, an ac-

count of which you will find on page 13 of the *Iron Trade Review* of May 31, 1900.

The world's blast furnace record was broken twice in the past year; once by a new stack at Carrie Furnaces with 790 tons of iron produced in 24 hours, and later by one of the National Steel Company stacks at Youngstown, producing 806 tons in 24 hours.

Regretting that we cannot cover more ground, and trusting the above will be of service to you, we are,

Yours very truly,

JNO. McLEOD.

Assistant to President.

Information and data regarding locomotives:—

BALDWIN LOCOMOTIVE WORKS.

PHILADELPHIA, November 11, 1901.

DEAR SIR:—

Replying to your favor of the 6th inst. we enclose a list of statistics giving the yearly output of the Baldwin Locomotive Works and the number of locomotives exported during the last ten years, also a description of the present organization of the works. You will note that for the year 1900, 1217 locomotives were constructed; during the first six months of the current year 640 locomotives were built, since July 1901, and at the present time, the construction is at the rate of 1500 locomotives per annum.

We consider the Atlantic type of locomotives for fast passenger service one of the most notable types of recent construction. Many of this type have been built during the present year. The type was originated by the Baldwin Locomotive Works in 1895, and has proved itself eminently adapted to the service for which it was designed. Various roads have adopted it under another name, but still retain the broad principle of the Atlantic type. It has also been reproduced on foreign roads.

We send a photograph of one of the original locomotives of this class, also one which has been built during the last year. The dimensions of each will be found on the backs of the photographs.

The heaviest locomotives in the experience of these works were built for the Lehigh Valley Railroad, to operate on the mountain grades near Wilkesbarre. They are of the consolidation type, with compound cylinders of the Vauclain four-cylinder compound system, and are equipped with Wootten boilers. The boilers have 4,100 square feet of heating surface, and the locomotives weigh, in working order, 225,000 pounds, exclusive of the tender, 202,000 pounds of the weight being on the driving wheels and utilized for adhesion. The locomotives were guaranteed to haul 1,000 net tons, exclusive of the weight of the engine and tender, up a grade of 66 feet in a mile, at a speed of 7 miles per hour.

A number of locomotives have been built in the past year equipped with the Vanderbilt boiler. We send you, under separate cover, a pamphlet containing an address by Cornelius Vanderbilt which explains the whole system. We also send a copy of our "Record of Recent Construction" No. 20, describing Atlantic type locomotives, and other recent numbers of this publication, which may contain something of interest to you.

With regard to the size of the locomotive which may be expected in the future we will say that for all existing classes the weights have doubled in the past 25 or 30 years. The average weight will undoubtedly further increase in the near future, and in some cases by increasing the number of driving wheels a greater total weight may be obtained in individual cases. The maximum weight per axle for a 100 pound rail seems already to have been established and utilized in many instances. It is therefore doubtful if axle loads exceeding 55,000 pounds will be used for some time to come.

For a prophecy as to the locomotive of the future, we refer you to *Record* No. 25 which contains an article by our Mr.

S. M. Vauclain entitled "Locomotives of the Nineteenth and Twentieth Centuries."

If you desire photographs or further information regarding any of the matter illustrated in the pamphlets, please advise us.

Very truly yours,

BURNHAM, WILLIAMS & CO.

R. H. Sanford.

BALDWIN LOCOMOTIVE WORKS.

STATISTICS.

Production of locomotives in each of the last ten years and percentage of total constructed for export:

Year.	Total Output.	Exported.	Per cent.
1890	946	144	15.2 %
1891	899	290	32.25%
1892	731	127	17.37%
1893	772	162	20.98%
1894	313	132	42.17%
1895	401	151	37.65%
1896	547	289	52.83%
1897	501	205	40.91%
1898	755	348	46.09%
1899	901	375	41.62%
1900	1217	363	29.82%

Number of locomotives turned out daily at the rate of 4½.
" " " " " yearly, 1,500.

Weight of lightest locomotive.. 5,000 lbs.
Weight of heaviest " ....225,000 "
Total tons of castings per day.. 135
Heaviest travelling crane, electric ....100 tons capacity.
Number of patterns in existence...43,741
Bolts and screws made per week........................... 175,000
Floors of work shops calculated to support a live load of 350 lbs. per square foot.
Approximate price per pound of engine and tender combined, calculated on net empty weight: Small, 12 to 14c; Medium, 10c; Heavy and extra heavy, 8c.
Wages paid each week ....$130,000 average.
Largest diameter of driving wheels...84½ in.

Number of men employed	10,300
Hours of labor per man per day	10
Principal departments run continually, hours per day	23
Horse power employed	7,000
Number of buildings comprised in the Works	33
Acreage comprised in the Works	16
Number of dynamos for furnishing power	9
Horse power dynamos for furnishing power	1,800
Number of dynamos for furnishing light (a c)	8
(incandescent)	5
Horse power of electric motors employed for power transmission, aggregate	3,500
Number of electric lamps in service (arc)	400
(incandescent)	3,500
Consumption of coal in net tons, per week, approximately	2,150
" " iron " " " " "	3,500
" " other materials " "	1,000

H. K. PORTER & CO.
LIGHT LOCOMOTIVES,

DEC. 13, 1901.

DEAR SIR:—

Replying to your esteemed favor of the sixth instant, I wish to apologize for having overlooked making a reply to your favor of November 6th. I appreciate the purpose and value of the information which you wish to acquire along the lines of our special work, and particularly as it has been taken up and put into execution by many of the large locomotive builders.

As you undoubtedly understand, our special work has been the design and construction of all types, sizes and guages of locomotives for the lighter class of general railroad and industrial work, and we have confined ourselves to the building of locomotives having cylinders not to exceed in diameter and stroke 17x24 inches, and the greater part of our product is the class of locomotives with cylinders averaging between 6 and 14 inches. It would be difficult for us to specialize our work in any way, inasmuch as we have had a very large demand for types of light locomotives very different in general appearance

and construction, dependent entirely upon the work that they had to do. For instance, we believe that we have especially achieved signal success in the construction of narrow gauge locomotives for the heavy class of steel works service. We have also had to meet an increasing and very extensive demand for a 3 foot gauge type of locomotive, weighing about 12 tons, cylinders 9x14 inches, specially adapted to the use of contractors who have been responsible for the actual work entailed in the new construction of so many miles of our railroads throughout the country. There seems to be a growing field for the use of light locomotives not only in the United States, but abroad; and we often find ourselves in a position where we have under construction on our erecting floor possibly twenty to twenty-five different types of machines, in regard to general design, gauge, &c., and all being hurried to completion at the same time.

In the last ten years we have embarked in the construction and design of pneumatic locomotives for underground and surface haulage, and we have developed an increasing and special demand for this type of machine; and to-day we have these locomotives in very general use throughout the United States. They are used very generally for underground haulage in the anthracite and bituminous mine districts of Pennsylvania, also they have been introduced in the copper and ore districts for underground haulage, as well as for surface haulage.

We have just completed a large plant for the Anaconda Copper Mining Company of Anaconda, Montana, for handling surface cars exclusively throughout their entire plant, which includes stamping mills, etc., etc. We have also completed two very important installations for the United States Government, storing up air at 1,000 pounds pressure and operating locomotives having 12x16 inch cylinders and weighing complete in working order 22 tons. These are the heaviest pneumatic locomotives that have ever been designed and constructed

and placed in active and successful operation in either this country or abroad; and while both electricity and compressed air have their well defined and particular fields for successful operation, compressed air is unquestionably winning favor in many instances where electricity was previously presumed to be the only economical and practical source of power.

We have not written you very concisely or very clearly, possibly, but if any part of our communication will serve your purpose in presenting this company and its products before your interested hearers we will be well pleased.

Yours very truly,
E. P. LORD.

MR. HENRY W. FISHER,
Care of Standard Underground Cable Co.,
Pittsburg, Pa.

PITTSBURG, PA., Jan. 21st, 1902.

DEAR SIR:—

Your suggestion that I write you briefly with reference to some of the most important or most interesting developments of the past year in the line of insulated cables for electric use, is noted, and I am very glad to call your attention to the following:

Perhaps the most important installation of the past year is the equipment, electrically, of the lines of the Manhattan Street Railway Co., of New York City. In this case the current is transmitted at about 11,000 volts through three conductor cables to suitable stations, where it is stepped down and transformed into direct current before being tapped into the third rail. On the initial, and we might say preliminary, installation, about 350,000 feet of cable has been used, each conductor No. 3-0 B. & S. G., insulated by 7-32″ paper, and then the three conductors spiraled together around a common center, with a like thickness of paper insulation placed over the three; this is then covered with 9-64″ lead sheath. These cables are tested

at factory at 30,000 volts, and after installation at 22,000 volts. This installation is particularly notable, in that the specifications for manufacture of the cable take into consideration the fact (which has been so long and persistently ignored by many engineers) that high insulation resistance in megohms is no criterion of a trustworthy and safe working cable. The relatively low insulation resistance of 200 megohms per mile to which this cable is manufactured, permits the use of softer waxes in the insulating compound, with a corresponding gain in puncture or high voltage tests.

It may be a matter of interest to also note the fact that during the past year this company has, in the face of very severe German and English competition, taken an order in the City of Mexico, for about 200,000 ft. of cable of a type which is but little used in the United States, although very extensively used throughout England and the continent. This cable, in addition to being insulated and lead covered in the usual manner, is provided with a heavy bedding over the lead, and then protected by means of two spirally wound steel tapes, which are in turn protected by a double saturated bedding over all. Cables of this class are intended to be laid directly in the earth without use of conduits or manholes, and while we do not, except under the most unusual circumstances, recommend this style of cable installation, it is a point worth noting that American manufacturers can compete with English and continental cable makers in the field of their own special products, and without any advantage in the score of freight, or otherwise.

There has been a continuation of the remarkable demand for equipment of telephone exchanges and systems by companies operating in many cases in opposition to the Bell Tel. Co. and its licensees. Such installations have now extended to the larger cities, of which we have furnished and in many cases installed the complete equipments in the following, namely:— St. Louis, Detroit, Indianapolis, Columbus, Cleveland, Pittsburg, Baltimore, Rochester, Wheeling, etc. It is not an ex-

ceptional matter for such exchanges to require 500,000 ft. of telephone cable for an initial installation, and many of them have considerably exceeded 1,000,000 feet.

We do not mention the points cited above as exceptional orders for us in point of size or importance, but rather as indicative of the most important or noteworthy examples of the business of the past year.

Yours truly,

Standard Underground Cable Co.

Per. J. MUARST,

Vice-Pres. & Gen'l. Mgr.

I have taken up so much of your time in presenting these various letters that what I have to say in conclusion will be brief. We are certainly indebted to the contributors for much instructive information, and we can with assurance look forward to the early part of this century for substantial developments in lines suggested by the manufacturers. The field of engineering is so broad that of necessity only a small portion can be covered in one address.

A number of other letters were sent out to which there were no responses. The railroad companies were all too busy to make any statements. The Pittsburg Plate Glass Co. had nothing new to report in the manufacture of plate glass.

Mr. F. J. Coe, of the American Locomotive Company, referred to a most interesting paper which he read before the New York Railroad Club, supplement to Vol. 11, No. 9. To those particularly interested in locomotives this is worthy of careful study, as the facts reported are extremely interesting. The heaviest locomotive weighed over 200,000 lbs., and the greatest power generated in a passenger locomotive was over 1500 HP.

Of radically new industries the manufacture of Nersst lamps in this city is no doubt the most prominent. These

lamps require only about one-half the energy of ordinary incandecent lamps but give the same amount of light.

This address is already much longer than was contemplated by the writer, and hence in conclusion I wish to thank the Society for the honor conferred upon me, and to apologize for any shortcomings during my term of office.

MR. EDWARD B. TAYLOR,

FIFTH PRESIDENT OF THE SOCIETY, 1886.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

The two hundred and twenty-second regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture room of the Society's house, 410 Penn ave., Pittsburg, Pa., Tuesday, February 18, 1902, at 8:30 o'clock, with the President, Mr. Charles F. Scott, in the chair, and thirty-eight (38) members and visitors present.

The minutes of the preceding meeting were read, corrected and approved.

The Board of Directors reported the names of six applicants for membership that have been approved, and were to be voted on at the next regular election.

The following persons were then balloted for and duly elected to membership.

SVEN S. EKMAN, - - -	Mechanical Draughtsman, Westinghouse Machine Co., East Pittsburg, Pa., h., P. O. Box 50, Wilkinsburg, Pa.
WILLIAM P. ENGLEMAN, -	Draughtsman, With National Tube Co., 709 Empire Bldg., Pittsburg, Pa., h., P. O. Box 140, Wilmerding, Pa.
FRED. R. HERTZOG, - -	Chief Mechanical Engineer, Tate, Jones & Co., Pittsburg, Pa., h., 6800 Simen avenue, Pittsburg, Pa.
ERIC L. HOOFRING, - -	Master Mechanic, Lincoln Foundry Co.,Pittsburg,Pa., h., Lang avenue, E. E. Pittsburg, Pa.
DAVID M. HOWE, - - -	Manager, Jos. Dixon Crucible Co., Pittsburg, Pa., 201 Lewis Block, Pittsburg, Pa.
BERTROM M. KERSHNER, -	Electrical Engineer, Pittsburg Railway Co., Pittsburg, Pa., h., No. 5 Cedar street, Bellevue Pa.

JOHN L. KLINDWORTH, - **Mechanical Engineer,** **Jones & Laughlin, Ltd., Pittsburg, Pa., h., 1610 Chartiers street, Allegheny, Pa.**

MORRIS KNOWLES, - - **Resident Engineer,** **Filtration Dpt., Public Works, Pittsburg, Pa., h., 5656 Callowhill street, E. E., Pittsburg, Pa.**

WILLIAM FRANKLIN MILLER, **Assistant Engineer,** **County Roads, Allegheny County, Pa., Room 28 Court House, Pittsburg, Pa.**

HUGH ELY MYERS, - - **Chemist,** **U. E. & F. Co., Lincoln Foundry Co. Dp't., 60th & Butler streets, Pittsburg, Pa.**

BERT IRWIN WELLER, - - **Civil Engineer,** **The Firth Sterling Co., Demmler, Pa., 405 Ross avenue, Wilkinsburg, Pa.**

THE PRESIDENT—Mr. Swensson, do you wish to bring up the question of the constitution this evening for discussion?

MR. SWENSSON—Not this evening.

THE PRESIDENT—When the present officers were elected a short time ago, I wished to know what duties the constitution prescribed for me, as well as what was called for on the part of the other officers and members. I spent an evening with the Secretary looking over the old papers and documents of the Society. We found only the charter. A constitution was prepared and printed a few years ago, but seems never to have been formally acted upon. The Board of Direction discussed this matter, and will consider the proposed constitution, and report to the Society. I would suggest that the members each secure a copy, as the matter will come up for further discussion later on.

THE PRESIDENT—Dr. W. B. Phillips, who prepared the paper for this evening, is unfortunately unable to be present, and Mr. Camp will read it.

DR. WM. B. PHILLIPS.

THE IRON RESOURCES OF TEXAS.

DR. WM. B. PHILLIPS.

It is not the purpose of this paper to deal, *in extenso*, with the various deposits of iron ore in Texas, for it is to be presumed that an audience of this kind is already sufficiently acquainted with the subject to render particular descriptions entirely unnecessary. The matter has been threshed over so many times in the publications of the geological survey of Texas, in the technical journals, and in the Transactions of the American Institute of Mining Engineers, that one may be pardoned for not mentioning every deposit and quoting analyses innumerable.

It has been known for many years that in the eastern, or rather in the northeastern, part of the State, there are extensive deposits of good limonite (brown ore), and that in the central part, in the county of Llano, etc., there are deposits of hematite and magnetite of excellent quality but unknown extent. It is also known that; up to this time, no workable deposits of coking-coal have been found in the State. So far as concerns the fuel question and local production of pig iron, Texas must use charcoal, or bring in coke from the Indian Territory, Colorado, New Mexico, or Alabama. With our present lights we can put to one side the use of lignite as fuel in the blast furnace. Whatever success might accompany its use in a small furnace and on a very limited scale (and this is problematical), no metallurgist or blast-furnace manager could advise the use of it on a commercial scale. There may be one or two little tea-pots using lignite and making a few tons off-grade iron in some out-of-the-way places, but in this country the use of lignite as a blast-furnace fuel is not even a Will-o'-the-Wisp,—it is merely a belated lightning bug trying to get home before sunrise.

It is a fact that in northeast Texas and in the counties of Rusk, Marion, Cherokee, Cass, etc., there are deposits of good

limonite of sufficient extent to warrant operations on a large scale. These ores are of the usual brown ore type, and carry from 45 to 50 per cent of iron and from 0.30 to 0.60 per cent of phosphorus. It is also a fact that they can be mined cheaply and that washing would, for the most part, *not* have to be resorted to. It is also a fact that these ores have been and are now used for the production of charcoal iron, and the total output of such iron from 1872 to the end of 1900 was 120,438 tons. Pardon me, but it is also the fact that this iron has an excellent reputation and buyers of charcoal iron are anxious to get it. And yet the industry languishes. *Why* it languishes is too long a story now. As this is not a discourse on the diseases of the iron business, we will forbear.

In an instructive paper read before the American Institute of Mining Engineers, Virginia Beach meeting, 1894, Mr. Wm. Kennedy, an engineer resident in Texas and familiar with the east Texas iron ore belt, took occasion to say that the probable cost of the production of charcoal iron in east Texas was $12.01, which, in a postscript subsequently added, he reduced to $9.50. The testimony that was given before a Committee of Inquiry, 27th Legislature of Texas, 1901, was to some extent confirmatory of this lower cost. Mr. Kennedy's items of cost were as follows:

Cost of making a ton of charcoal iron in east Texas:

2½ tons of ore,	@	82c	$2.05.
110 bu. of charcoal,	"	4c	4.40.
½ ton of limestone,	"	$1.50	0.75.
Labor and salaries,			1.50.
Interest,			0.30.
Repairs and incidentals,			0.50.
			$9.50.

I think that this would probably represent the lowest cost, and that the average cost would be nearer $11.00 than $9.50, under present conditions. It is only in east Texas that pig

iron has been made, and the only ores that have come into use are the limonites of that region.

The hematites and magnetites of Llano County, in central Texas, 100 miles northwest of Austin, represent the best types of these ores. Some recent analyses of samples taken in person are as follows:

ANALYSES OF LLANO COUNTY MAGNETITE.
O. H. PALM AND S. H. WORRELL.

Metallic Iron,	66.33 per cent.	64.40 per cent.	64.40 per cent.
Silica,	2.38 " "	6.52 " "	6.54 " "
Alumina,	2.69 " "	trace	trace
Lime,	none	none	none
Magnesia,	none	none	none
Sulphur,	0.44 " "	trace	trace
Phosphorus,	0.032 " "	0.048 " "	0.045 " "

These ores were fully discussed by Theodore B. Comstock in the First and Second Annual Reports of the Geological Survey of Texas, 1889 and 1890, and there is but little to add to what was said then. Few or no other developments have been made, and the matter stands now just where it did then, in so far as concerns our knowledge of the extent of the deposits. The average of 5 analyses of Llano County magnetites given by Dr Comstock is as follows:

AVERAGE COMPOSITION OF LLANO COUNTY MAGNETITES.
ANALYSES BY J. H. HERNDON AND L. MAGNENAT.

Metallic Iron, ...	63.31	per cent.
Silica, ...	4.67	" "
Alumina, ...	5.74	" "
Lime, ...	0.57	" "
Magnesia, ...	trace	
Sulphur, ...	0.092	" "
Phosphorus, ...	0.064	" "

With respect to phosphorus it must be said that of the 5 analyses quoted 3 showed a trace, 1 showed 0.02, and the other 1.02 per cent. Excluding this last as abnormal, we would

have a very small amount of phosphorus in these ores. And yet these analyses clearly indicate that, while ores extremely low in phosphorus are to be found in this region, there is a possibility of their carrying more than the Bessemer limit of this element. The ores would be subject to rigid inspection and analysis if sold as Bessemer ores.

The average of 6 analyses of Llano County hematites, given by Dr. Comstock, is as follows:

AVERAGE COMPOSITION OF LLANO COUNTY HEMATITES.
ANALYSES BY J. H. HERNDON AND L. MAGNENAT.

Metallic Iron,	56.43	per cent.
Silica,	5.59	" "
Alumina,	7.86	" "
Lime,	1.44	" "
Magnesia,	trace	
Phosphorus,	0.55	" "
Sulphur,	0.091	" "

It is to be noted that in one of the samples there was 3.12 per cent of phosphorus, corresponding to 7.16 per cent of phosphoric acid. This is a most unusual amount of phosphorus in ore of this character. On the other hand two of the samples showed a trace of phosphorus. The alumina is high, one of the samples giving 17.11 per cent, another 14.50 per cent, the average running to 7.86 per cent.

There are other parts of the Central Mineral Region that yield good magnetites and hematites, as the counties of Gillespie, Mason, McCollough, etc.

In Llano County considerable prospecting was carried on 10 or 12 years ago, at Bessemer, 9 miles east of the Town of Llano, and at Iron Mountain, 15 miles northwest of Llano, on the magnetites of these localities. South of Iron Mountain a diamond drill hole was carried down to a depth of 600 feet, with the following reported section to 517 feet:

SECTION OF BORE-HOLE,
SOUTH OF IRON MOUNTAIN, LLANO COUNTY

Granite,	301	feet:
Magnetic ore,	40	"
Granite,	25	"
No core but thought to be ore,	13	"
Granite,	27	"
Chloritic rock and granite	36	"
Magnetic ore,	7	"
Granite and schist,	13	"
Granite,	55	"
	517	feet.

An analysis of the ore from this property was made by Andrew McCreath, Harrisburg, Pa., with the following results:

ANALYSIS OF ORE FROM BADER MINE, SOUTH OF IRON MOUNTAIN, LLANO COUNTY.

Metallic Iron,	64.15	per cent.
Silica,	7.28	" "
Titanic Acid.	0.38	" "
Phosphorus,	0.014	" "

Attractive as are some of the iron ores of this region, from a chemical standpoint, it cannot be said that they have been sufficiently prospected to enable one to speak with confidence of their extent. In places they seem to be of commercial importance, and at one time it was hoped that they would be mined. But the enterprise fell through, and the machinery that had been installed was removed. For several years nothing has been done.

Of late, however, there has been a revival of interest in these ores, as well as in those of East Texas. It was stated that, so far as known, there were no deposits of coking coal in Texas. This statement applies to such coal as is now mined and to the ordinary bee-hive coke oven. But it is well known

that some coals which do not yield good coke in a bee-hive oven, do yield a fair coke in a recovery oven, such as the Solvay, the Hoffman, the Carves, the Huessener, etc. We are no longer restricted to the use of the bee-hive oven, for the improvements in the so-called recovery ovens now allow the use of an inferior coal for coking. I do not mean to say that the coke is as good as it would have been if better coal were used, but that it can be successfully used in the blast furnace. In other words, we can now make passably good coke from coal that would have been considered entirely unsuited for the purpose a few years ago. This fact has an important bearing on the utilization of the Llano County ores. A study of the map of Texas will show that the shortest route from the town of Llano to the producing coal fields, we will say to Strawn, in Palo Pinto County, is 347 miles. If coke were made in Palo Pinto, Erath, Eastland, or Stephens, it would have to be hauled 350 miles to the ore, or the ore hauled 350 miles to the coke. But there will be built this year a connection between the Houston & Texas Central Ry. at Burnet to the Gulf, Colorado & Santa Fe Ry. at Lampasas, 30 miles, that will reduce this distance to 280 miles, a gain of 70 miles.

Furthermore, it is not improbable that among the undeveloped coals of Stephens County, north of the Texas & Pacific Ry. at Bangor, there may be found some more suitable for coking than those already opened in that part of the carboniferous area. To open the Stephens County coal would require from 20 to 30 miles of road, so that we may say that the distance from the Llano ore fields to the coal fields, even after the completion of the Burnet-Lampasas branch, will be about 300 miles. It has been proposed to use the Llano County ores in furnaces already built, mixing them with the brown ores spoken of. The distance from Llano to the nearest blast-furnace, viz., at Rusk, is 293 miles (the New Birmingham furnace is near Rusk), while to the furnace at Jefferson, Marion County, it is 370 miles. It is about the same distance from

Llano to the nearest furnace as from Llano to the coal fields, and if Llano ore should be hauled to Rusk, New Birmingham, or Jefferson, it would have to be turned into charcoal iron, for the furnaces in east Texas are not built for coke-iron.

But it has also been proposed to bring Indian Territory coke into the east Texas ore district. This would necessitate an all rail haul of 270 miles to Jefferson, and also to Rusk and New Birmingham. The east Texas ore fields are about 270 miles from South McAlester. So far as our present knowledge goes, we can say, therefore, that the shortest haul between the Texas iron ore districts and coking coal is 270 miles. If coking coal should be discovered in the Texas carboniferous the haul to the Llano ore district would be 300 miles, and to the east Texas ore district about the same. The Indian Territory coke would have an advantage of thirty miles as against Texas coke in the east Texas ore fields, but Texas coke—supposing, for the moment, that we had Texas coke—would have an advantage of 180 miles in the Llano ore district. Now, a thirty-mile haul, in a total distance of nearly 300 miles, cuts but a slight figure, so we may say that, if coking coal can be developed in the Texas carboniferous, it would compete on equal terms with Indian Territory coke in east Texas, and would have a decided advantage in the Llano district.

It has also been proposed to export the Llano ores, by way of Galveston, to Baltimore, or Philadelphia, or even across the Atlantic. From Llano to Galveston is 319 miles, but little more than from Llano to the coal fields. Whether Llano ore can find a market in this way remains to be seen. The distance from Galveston to Baltimore is 1,800 nautical miles (making the total distance from Llano to Baltimore 2,390 statute miles), while the distance from Santiago de Cuba or Daiquiri (large ore exporting ports on the southeast coast of Cuba) to Baltimore is 1,300 nautical miles. It would require an ore of exceptional purity and of guaranteed composition to compete successfully with Jurugua or Spanish-American ore

in markets already familiar with Cuban ore. The duty of forty cents per ton on imported ore plays no great part in this matter, for it is rebated if the materials manufactured from it are in turn exported.

Still another plan has been suggested of late, and that is to ship Llano ore to Missouri furnaces, or to the furnaces at East St. Louis, in Illinois. The distance from Llano to St. Louis is 918 miles, and it is to be supposed that the chief reason why this long all-rail haul is considered at all is because of the uncertainties and delays attending the shipping of Lake ores to these furnaces during the winter months. From St. Louis to Duluth is 884 miles, by way of Burlington, Cedar Rapids and St. Paul. From Duluth to Mountain Iron, the heart of the Mesabe Range, is 72 miles, making the distance from St. Louis to Mountain Iron 958 miles, as against 918 miles from St. Louis to Llano. To some of the Old Range or Wisconsin mines from St. Louis it is not so far as to Duluth; probably ore could be laid down at St. Louis with a 750-mile haul. But, at any rate, the distance from St. Louis to available ore in the North is less than from St. Louis to the Llano ores, while the freight rates are also less. Of course, some lake ore is hauled by rail to points from 800 to 1,000 miles distant, but the conditions seem to be such as would not readily maintain were the attempt made to ship Llano ore as far as this by rail. The enormous output of the lake mines, the regularity of the car supply and other industrial factors, outweigh the shortage due to occasional blizzards and seasons of very cold weather.

What demand is there in Texas for pig iron, or bar iron, or rolled shapes of iron or steel? This question cannot be answered definitely, because there is no practical way of collecting the actual statistics. We know, of course, that Texas is an agricultural and grazing State, for the most part, and that industries other than agriculture which require large quantities of iron and steel have not yet been developed.

The farming industry in Texas is certainly very large, and steadily growing larger. It requires a great deal of iron and steel, taking one year with another, and these supplies are furnished almost entirely from beyond State limits. The population of the State is increasing rapidly, having gained 36 per cent. between 1890 and 1900, leading all the Southern States. It is now 3,048,710. The railroad mileage, June 30th, 1901, was 10,153 miles. There are now about sixty foundries in the State, and possibly half a dozen good machine shops, excluding those owned and operated by the railroads. I made the attempt to gather certain data from the foundries, and to this end sent out a letter to each one asking replies to the following questions:

1. Where do you get your pig iron?
2. What kind of pig iron do you use?
3. What class of castings do you produce?
4. What is your daily capacity in tons?

Replies were received from forty establishments, representing more than 95 per cent. of the foundry business in Texas. The replies to the first question show that the pig iron used comes from Texas, Alabama, Tennessee, Georgia and Ohio. There were seven that used Texas iron exclusively and three that used Texas iron in conjunction with Alabama iron. One firm writes: "We get our pig from Alabama, but would prefer Texas iron if we could get it." Another, and a large and important establishment, writes: "We beg to say that for several years past, not being able to get a supply of Texas pig iron, which we much prefer to any other brand for use in our business, we have been forced to use pig iron made in Alabama and Georgia." A large consumer of pig iron in the Central West said to the writer recently that he had endeavored to secure a three-year contract for Texas iron, but had been unsuccessful because of the alleged inability to supply the amount desired. Of the establishments replying, eighteen used Alabama pig exclusively, while eleven used

Alabama pig in connection with pig from other States. It appears that Alabama iron is used more extensively in Texas than any other kind. The kinds of pig iron brought here are, of course, Nos. 1 and 2 Soft, and the regular foundry grades, even as low as No. 4 F, which is sometimes known as foundry forge.

The class of material turned out includes machinery, and architectural work, engine and mill castings, farming implements, light steel castings used in plows (one establishment), railroad, bridge, hydraulic oil press, in fact nearly all kinds of castings. There is no malleable iron plant in the State.

The daily capacity was 271 tons, distributed among 36 establishments. Most of the establishments, however, are small, 8 of them accounting for 190 tons, leaving 81 tons for 28 plants. Three of the establishments report a total daily capacity of 135 tons, these three having 25, 50, and 60 tons respectively. Not all of the total daily capacity of 271 tons is to be considered as pig iron, for a considerable amount of scrap is used, the exact proportion not being known, depending, as it does, upon the kinds of castings required, etc. Perhaps one would be safe in assuming that one-half of the total daily capacity represents the pig iron used, in which case we would have 135 tons. I think it would be safe to assume 100 tons a day as the average consumption of pig iron, *as such*, in Texas, or 30,000 tons a year.

Of the consumption of pig iron in manufactured form there are no statistics, but we may arrive at a practical conception through the weight of the cotton ties used in bagging the crop of 1900. This was about 13,500 tons, worth $1,500,000. The average cost of the ties is 50c per bale, and the crop of 1900 was in excess of 3,000,000 bales of 500 pounds each. Not allowing for any wastage between pig iron and cotton tie—although there is, of course, a considerable waste, utilized, however, in other ways—we have 43,500 tons of pig iron con-

sumed annually by the Texas foundries and by the makers of cotton ties used in bagging the Texas cotton crop.

To this must be added the wire fencing, wire nails, jobbers hardware, architectural, agricultural and railroad iron, etc., which would, I think, bring the total up to at least 60,000, tons a year, exclusive of steel rails, merchantable steel, and malleable castings. In other words the amount of iron made in Texas from 1872 to 1900, a period of 29 years, would just about supply the demand of two years, excluding rails, steel and malleable castings.

Now the question is, can a considerable proportion of the pig iron used in Texas be made in Texas and from Texas materials? This is purely a business matter, and has nothing to do with sentiment. It is strictly a matter of dollars and cents, and must be regarded solely from this standpoint.

There is plenty of ore in the State and of a quality that is very largely used elsewhere; can it be utilized? Considering the fact that, *so far as now known*, there is no coking coal in the State, the manufacturs of pig iron must depend upon the use of charcoal as fuel, or upon coke brought in from the Indian Territory, the nearest source of supply, over a distance of 270 miles from the east Texas district, and 480 miles from the Llano district. The only native fuel is charcoal. Coking coal *may* be discovered and brought into use, but at the present time the only known fuel is charcoal, for lignite is not in the running.

There is an opportunity in east Texas for the production of charcoal iron, and a 50 or 60 ton furnace would probably do well there. The product would find a ready sale in Texas, for there are four foundries already in operation that would consume the entire product. As already remarked, the iron that has been made there has a good reputation and is in demand, specially by the makers of car-wheels and plow castings. An output of 60 tons per day could readily be marketed at satisfactory prices. It is true that the charcoal and

limestone would have to be hauled considerable distances, but even under these conditions it is not improbable that iron could be made for $10.00. I am aware that the charcoal iron industry has been in a decadent condition for several years, and that the present output of about 300,000 tons is nearly 300,000 tons less than for 1890. But here is a territory that is to a large extent cut off from the great centers of iron production and yet uses 100 tons of pig iron a day for foundry purposes. The decadence of the charcoal iron industry merely goes to show that coke iron has taken its place in certain districts and for certain purposes; it does not prove that it could not be established in Texas. The Texas iron trade is essentially a foundry trade and the largest establishments would be glad to get charcoal iron, and this is substantiated by numerous letters now in my possession.

Furthermore, a steel cotton-tie and wire plant, making also small steel castings, would have a very large area within which to market its products. Of cotton-ties alone the three States of Arkansas, Louisiana and Texas in 1900 used $2,211,000 worth. It is impossible to speak positively of the wire trade, for there are no statistics available, but it is not unlikely that it is worth, in these three States, $500,000, making a total for cotton-ties and wire of $2,711,000.

A charcoal furnace for foundry iron and a coke furnace for iron destined for the steel plant, pipe, etc., would probably be an advisable combination. Beaumont oil or Corsicana residuum could be used for fuel in the steel furnace, as also in the foundry, and could be delivered within the iron ore district of east Texas for 40c per barrel. The distance from Beaumont to Rusk is 158 miles, and from Corsicana to Rusk 120 miles, from Beaumont to Jefferson 262 miles, and from Corsicana to Jefferson 158 miles. Recent contracts for the delivery of the Beaumont oil within distances varying from 250 to 300 miles have been made at 44½c per barrel. The Nacogdoches oil field (not, however, producing now) is within 80 miles of Rusk, and

148 miles of Jefferson, so that the estimate of 40c a barrel for Beaumont oil in the ore district is certainly not too high, and it is likely that it could be delivered for a price considerably below this. At 40c a barrel and 4 barrels per ton of coal we would have $1.60 as the price of oil equivalent to a ton of coal. It is to be observed, of course, that the oil is for use only in the puddling furnaces, in the steel furnaces, or in foundries (for core ovens, etc.). It cannot be used alone, or in admixture with lignite, as a blast furnace fuel. I would not tax your patience with this statement were it not for the fact that I have received letters of inquiry on this very point. There seems to be a belief in certain quarters that crude oil can be used in the blast-furnace in place of coke or charcoal, but this belief is not shared by those who are familiar with the requirements for blast furnace fuel. As you know, it takes a good deal more than mere heating power to supply the demands of a blast furnace. Crude oil is valuable for many purposes, but the time has not yet come when it can supplant solid fuel for iron making. Coke, anthracite coal, splint coal and charcoal will continue to be used long after we have passed away.

From an examination of all known facts and reasonable deductions therefrom, I think it probable that iron making could be established in Texas on a commercial scale and with fair prospect of success. There is nothing like enough iron produced in the State to supply the present demand, the State is growing rapidly and many industries are springing up, consequent, among other causes, upon the discovery of large stores of cheap fuel oil.

Within 175 miles of Rusk and in Texas alone there is a daily capacity of the foundries in excess of 225 tons, pig iron and scrap, of which about one-half is pig iron. Within a distance but little further from Jefferson the same statement holds good. The ore fields of east Texas are within two hundred miles of the most densely populated region in the State,

and one that is increasing in wealth and in iron-consuming power every year. It is true that the east Texas iron ores are not of a high grade, but they are of as good a quality as brown ores generally, and in the country at large there were mined in 1900 3,231,089 tons of ore of no better quality. The lowest average value per ton of ore in 1900 was reported from this State, 82c a ton. This may have been due to the fact that convict labor is employed, but experience elsewhere has shown that convict-mined ore and coal are but little, if any, cheaper than the coal and ore mined with free labor. The main benefit derived from the use of convict labor is, perhaps, due to the uninterrupted control of it, not to any marked decrease in the cost of production aside from this fact.

There are four furnaces in Texas now, all of them built for charcoal, and all of them in the east Texas district. These are as follows:

Jefferson Furnace, Jefferson, Marion County. One stack 60x12, built in 1889-91, blown in March 15, 1891. Two Durham iron stoves. Capacity, 13,500 tons. A rolling mill was partly finished in 1891, and was designed to contain 15 single puddling furnaces, 3 heating furnaces, and 3 trains of rolls (one 18 in. muck and one 8 in., and one 12 in. bar).

Old Alcalde Furnace, Rusk, Cherokee County, owned by the State of Texas. One stack 55x9½. Built in 1883 and put in blast February 27, 1884. Hot blast. Capacity, 7000, tons. A pipe foundry is connected with the furnace.

Star and Cresent Furnace, near Rusk, Cherokee County. One stack 65x11. Built in 1890-91 and blown in November, 1891. Iron Stoves. Capacity, 18,000 tons.

Tassie Bell Furnace, New Birmingham, Cherokee County. One stack 60x11, built in 1889-90, and blown in November, 1890. Two Weimer pipe stoves. Capacity, 13,500 tons.

During the last 10 years, therefore, there have been 4 charcoal furnaces capable of making iron, with a total annual capacity of 52,000 tons. But during this period, i. e. from

1891 to 1900, inclusive, the total amount of iron made was only 71,412 tons. With a total capacity during these 10 years of 520,000 tons the actual output was 71,412 tons, or 13.7 per cent of the capacity. We have the statistics of the production of pig iron in Texas since 1872, with the exception of two years, 1875 and 1878, when the output may have been 500 tons each. The total amount of pig iron produced during these 29 years, 1872-1900, inclusive, was 120,438 tons. As already remarked, this is about enough to supply the demand for 4 years, while the furnaces in the State could produce it in 28 months.

We have not considered other deposits of iron ore in the State, as, for instance, in El Paso County, west of the Pecos River. But little is known of them, although some excellent samples have been received. Some of the El Paso ores closely resemble the Llano magnetites. They lie at some distance from rail, and may not be available. They occur in the Quitman Mountains, the Sierra Diabolo, Sierra Carrizo and Chinatti. In the Quitman Mountains, according to Von Streeuwitz, carbonate of iron is also found.

In Gonzales and Caldwell counties, near Harwood, on the Southern Pacific Railway, 64 miles east of San Antonio, there are beds of limonite of good quality.

In this paper the attempt has been made to consider the iron resources of the State in a general way, without inquiring into the merits of any particular deposit of ore or of any special location. The conclusions reached are as follows:

1. There are extensive deposits of limonite in east and northeast Texas, carrying from 45 to 50 per cent. of iron, but not suited for the manufacture of Bessemer iron. These ores can be cheaply mined, and can be delivered to the furnace for 80c. to $1.00 a ton.

2. There are deposits of magnetic and hematite ores in Llano, Mason, Gillespie, etc., of unknown extent, but of excellent quality.

3. The only available fuel is charcoal, unless Indian Territory coke can be brought in.

4. The total daily capacity of the foundries in the State is 271 tons, pig iron and scrap, of which at least 100 tons is pig iron.

5. There is an active and steady demand for Texas iron, and there would be little difficulty in marketing 100 tons a day within a distance of 150 to 200 miles.

6. The demand for pig iron, as such, is about 30,000 tons a year. Cotton ties call for 13,500 tons more, while wire fencing, wire nails, etc., would probably call for 16,500 tons. Exclusive of steel rails, merchantable steel and malleable castings, the consumption of iron, taken as pig iron, is probably about 60,000 tons a year.

7. The annual average production of pig iron in the State during the ten years, 1891-1900, is 7,141 tons, leaving 23,000 tons to be brought in from other States.

8. The cost of producing charcoal iron in east Texas should not exceed $11.00, and may be reduced to $10.00. On account of the long haul for coke, it is not likely that the cost of coke iron would be much less than that of charcoal iron.

WILLIAM B. PHILLIPS.

AUSTIN, TEXAS, February, 1902.

In absence of President, Vice-President Prof. F. C. Phillips in chair.

THE CHAIRMAN—The paper was a most excellent one, and we are sorry that Mr. Phillips is not present to help us out with the Mexican names, as well as to give us additional information. The discovery of charcoal iron in Texas is a very important one. It will undoubtedly lead to the founding of other industries.

MEMBER—Isn't $11 per ton a pretty cheap production of charcoal iron?

MR. BOLE—Where do you suppose the charcoal comes from?

MR. OSBORN—I will say that I am well acquainted in that section of the country, and in southeastern Texas, there is a tract of timber larger than the whole of the state of New York. It is south and east of the Llano Estacado, and consists of pine and hemlock and some of the hard woods. Coal was first mined in the Chickasaw Nation, Indian Territory, 108 miles from northern Texas.

THE CHAIRMAN—What is the quality of the Indian Territory coal?

MR. SWENSSON—Very good for making coke. Two hundred and seventy miles is not very far to carry coke.

MR. BOLE—Coke is sent to Chicago and west of there from the Connellsville region.

THE CHAIRMAN—The question of charcoal supply is a curious one. Some time ago, when in New York, I made inquiries as to where the supply of charcoal used there comes from, and was told that they had inexhaustible supplies, enough to last for years to come. There are still great forests in sections of the country, where we least expect to find them. The charcoal supply of Michigan is exhausted, is it not?

MR. SCHELLENBERG—It is the largest in the U. S. The principal field is the mainland east of Lake Michigan. Wood alcohol and acetic acid are also largely manufactured at the kilns.

On motion the meeting adjorned at 9:45.

CHARLES W. RIDINGER,

Secretary.

CHEMICAL SECTION.

Pittsburg, Pa., January 23, 1902.

The tenth annual meeting of the Section was held in the Society rooms, Chairman A. G. McKenna, presiding. In the absence of the Secretary, Mr. G. O. Leoffler was appointed Secretary *pro tem.*

The minutes of the last annual meeting were read and approved.

The Section then proceeded to ballot for officers to serve for ensuing year, resulting in the unanimous election of the following:

Chairman, . . .	Dr. K. F. Stahl,
Vice-Chairman, . . .	H. W. Craver,
Secretary, . . .	Chas. H. Rich,
Directors, . .	A. Gross, Philo Kemer.

There being no furthur business, upon motion, the Chairman declared the meeting adjourned.

G. O. Leoffler,
Secretary pro tem.

CHEMICAL SECTION.

Pittsburg, Pa., February 20, 1902.

The regular monthly meeting of the Section was held in the Society rooms, the Chairman, Dr. K. F. Stahl, presiding.

The minutes of the last regular meeting were read and approved.

Mr. Camp, for the program committee, reported progress.

There being no furthur business, the paper of the evening, "An Accurate Estimation of Sulphur in Iron by the Evolution method," prepared by Mr. H. E. Walters and Mr. Robt. Miller, was read by Mr. Walters.

The paper was discussed by Dr. Stahl, Prof. Phillips, Messrs. Camp, McKenna and Wilkins.

After a general discussion of matters of interest, the Section upon motion adjourned at 10 p. m.

CHAS. H. RICH,
Secretary.

AN ACCURATE ESTIMATION OF SULPHUR IN IRON BY THE EVOLUTION METHOD.

HARRY E. WALTERS AND ROBERT MILLER.

The estimation of sulphur in iron is a subject upon which a great deal has been written, and if apologies are necessary for our contributing to the literature of the subject, we can only say, that we think that the method which we present in this paper, solves the problem of securing an accurate estimation by the evolution method.

Dr. Phillips, of this Society, has shown that in using the evolution method, organic sulphur compounds are formed, which are quite volatile and pass through the absorbing solutions, and recently, Shimer and Blair, in a paper read at the Mexico meeting of the American Institute of Mining Engineers, have proven the presence of a carbon-sulphur-titanium compound in some irons which is insoluble in hydrochloric acid and point this out as a further source of error in using the evolution method.

Most of the investigations were carried on with white irons, while in our investigation, we have found the variation in results to be as much, and in most cases more, in grey irons.

It was suggested to us that if the sample be weighed off and then annealed in a non-oxidizing gas, that all of the sulphur could probably be obtained by the evolution method.

Samples of coke, foundry and cast irons, as well as a sample of iron containing titanium, were obtained and treated as follows:

1st. The sulphur was evolved by the regular evolution method, using an ammoniacal cadmium chloride solution to absorb the hydrogen sulphide and titrating the cadmium sulphide with iodine.

2d. The sample was weighed into a porcelain boat and annealed in a porcelain tube in a current of natural gas or

hydrogen. After annealing the sulphur was evolved and estimated as in (1).

3d. The sulphur was estimated by the gravimetric method.

The first sample tried, was a sample taken from an iron casting, which had been cast in sand. This sample showed .057 sulphur by the regular method. The sample, after being annealed and then evolved, as in the first case, showed .071 sulphur. The average of five results by the gravimetric method was also .071 sulphur.

From these results it will readily be seen that after annealing, all of the sulphur was evolved as hydrogen sulphide.

These results were so encouraging that the rest of the samples were then tried, and in every case, the result obtained after annealing, checked with the gravimetric result. Experiments were then instituted to find the amount of time which the annealing should require, and it was decided that for ordinary irons, fifteen (15) minutes would be sufficient, but if the samples contained an appreciable amount of titanium, they should be annealed one half hour.

The method finally decided on was as follows:

Weigh five (5) grams of the sample into a porcelain or copper boat and place in a thin porcelain or nickel tube, which is then placed in a combustion furnace, pass a current of natural gas or hydrogen through the tube a couple of minutes to expel the air and then ignite at the end of the tube. Now light the burners under the tube and turn on the gas so that the flame will just encircle the tube, and anneal at a bright red heat fifteen (15) minutes to one half hour. At the expiration of this time turn out the burners and allow the tube to cool while the current of gas continues. This will require about seven (7) to ten (10) minutes. When cool, remove the boat from the tube and transfer the sample to a suitable flask and evolve the sulphur with dilute hydrochloric acid (1 acid

1 water). Absorb the evolved hydrogen sulphide in an ammoniacal cadmium chloride solution. Titrate with an iodine solution of theoretical strength.

The following results will show how well the method compares with the gravimetric method:

SAMPLE.	REGULAR EVOLUTION METHOD.	EVOLUTION AFTER ANNEALING 15 MIN.	BA cl_2 METHOD.
1 Iron casting.	.057	.071	.070
	.057	.071	.071
			.071
			.071
			.073
2 Shot Sample.	.034	.039	.038
	.034	.039	.039
3 " "	.045	.051	.052
	.046		
4 " "	.049	.059	.059
5 " "	.080	.085	.086
		.084	
7 " "	.026	.026	.026
8 " "	.036	.035	.034
9 " "	.052	.051	.053
10 " "	.072	.078	.077
11 " "	.125	.132	.130
724 " "	.032	.031	.030
	.030	.030	.032
730 " "	.052	.051	.049
	.049	.050	.050
740 " "	.083	.081	.081
	.080	.082	.080
769 " "	.115	.119	.118
740 Pig	.081	.081	.080
	.080	.079	.080
2 Iron castings.	.025	.034	.030
	.024	.036	.034
	.025	.032	.034
B	.038	.056	.056
	.038	.055	.054
	.040	.057	.057
C	.059	.076	.076
	.059	.075	.074
	.060	.074	.075
12 Pig iron.	.044	.076	.076
	.043	.076	

Shot samples 2-11 came from the Edgar Thomson Furnaces, Duquesne Furnaces and the Carrie Furnaces of the Carnegie Steel Co. and Dr. Phillips of the Western University.

Shot samples 724, 730, 740 and 769 are from the Isabella furnace. These samples were heated to redness before being

crushed. This probably accounts for the results of the three methods checking so closely.

Sample of pig iron 740, is from the same cast as the shot sample 740.

Samples B. & C. are the American Foundrymen's Association standards.

No. 12 is a sample of iron containing titanium and 2.44 % silicon, and was kindly furnished to us by Mr. P. W Shimer, of Lafayette College. It required thirty (30) minutes annealing on this sample.

We think that, the method as outlined above, is practical because it requires but one hour to make the determination, and if a tube of large bore be used a large number of samples may be annealed at the same time.

While we should have liked to present more results, and also to have tried annealing in nitrogen and carbon dioxide, we could not find the time to perform any more experiments. We think that either of these gases will act as well as hydrogen or natural gas, and furthermore believe that if shot samples are heated to redness before they are crushed, they will need no further annealing, and all the sulphur will be evolved as hydrogen sulphide.

In conclusion we would suggest that some of the members of this Society try this method, and report their results to the Society at their earliest convenience.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and twenty-third regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the lecture room of the Society's house, 410 Penn ave., Pittsburg, Pa., Tuesday evening, March 18, 1902, at 8.15 o'clock, with the President, Mr. Charles F. Scott, in the chair, and one hundred and two members and visitors present.

The minutes of the preceeding meeting were read and approved.

The Board of Direction reported that they had consulted an attorney regarding the proposed Constitution, but that he had advised, in general, that the Charter should be supplemented not by Constitution, and that By-Laws should be made in conformity with the Charter, otherwise the Charter would have to be changed. The Board will hold a meetingon Saturday evening, March 22, at which time they will reconsider the proposed Constitution, and put same in shape to be presented tothe Societv at its next regular meeting.

The Board of Direction reported the names of eighteen applicants for membership that had been approved, and were to be voted on at the next regular meeting.

The following reports were received by the Board of Direction, Saturday evening, March 15th, and it was unaminously voted, by the members present, that the Society should act in accordance with the recommendation of the Committees, and the reports should be brought before the Society for its consideration.

To the Board of Directors.

Your House Committee beg to submit the following recommendations for your consideration:

Owing to the increasing membership, the evident revival

of interest and the position the Society now occupies, we recommend:

1st. That the Society arrange to occupy the two front rooms on the first floor of this building in addition to those now occupied by it.

2d. If these rooms can be occupied by the Society, that the library be removed from the lecture hall to the front rooms on the second floor.

3d. Fit up and furnish the two rooms first floor front for lounging rooms and office.

4th. Paper two rooms first floor front, front hall, stairs, second floor hall, coat room, two front rooms second floor, lecture room and vestibule.

5th. Carpet two rooms first floor front, front hall, stairs, second floor hall and room now used as an office on second floor with carpet. Cover floor of the lecture room with good medium quality of linoleum.

6th. Repaint all interior wood work.

7th. *Sign.* Paint plainly the name of the Society on the hall transom over the front door. Also on lower glass of each front window.

8th. *Heating.* Procure and install in the room under lecture room a suitable gas furnace, properly piped to two registers in the floor of the lecture room.

9th. Improve the ventilation in the lecture hall by extending air shaft and repairing same, so that it can be opened when occasion demands.

10th. *Furniture.* Replace the folding chairs now in the lecture room with others that will be more attractive and much more comfortable.

11th. *Coat Room.* It is almost certain that if the tenant now in the first floor rooms vacates she will give up room in the third floor. We would recommend making a store room of it and fix up the present store room for a coat room, as the present one is entirely too small.

Total estimate in accordance with bids already received, $811.75.

Respectfully submitted,
HOUSE COMMITTEE,
E. S. McClelland, Chairman.

To the Board of Directors:

Our library is to-day practically useless so far as reference goes, probably not being used ten times a year. We believe this is due to two things: first, the proximity of the Carnegie Library, with its complete and well catalogued lists; second, because our library is far from complete.

We know that our Society has not the money to devote to making a reference library which, even when finished, would approach the Carnegie in completeness. Therefore, we cannot help but think it is foolish to carry a large number of books of the nature of back government reports. We would recommend that the books of this type be given in trust to some other library, until such time as we have room for them, and the few book cases which we now have be filled with literature of interest and value, as a "reading," not a "reference library."

We have to-day ten cases which will not hold the number of books we own at present. About four of these are filled with the reports of agriculture, geology, water ways, etc., and we think if the Society keeps, say two or three of the last volumes on these various subjects it would be all that is necessary. There is at least another case of back numbers of periodicals, such as the Scientific American, American Engineer, Architect and Building News, etc., all of which we believe, from past experience, should be gotten rid of. This being done, we would then have an opportunity to use our present cases, and make a library which would contain the few standard technical works we now own, and bound proceedings of the scientific societies, in such shape as to be of use and benefit.

We would further suggest that, if possible, the House

Committee give the library such rooms that the current periodicals may be readily accessible and so that the Society may have both a library and a reading room; for the present we have nothing which could properly be called either. In a word, let us do away with the useless half of our library, and shape things so that they will be readable.

Yours very truly,

LIBRARY COMMITTEE,

Sumner B. Ely, Chairman.

PRESIDENT—The report of the Board of Direction makes certain recommendations based upon the reports of two committees. These committees have taken considerable trouble to canvas the subjects quite fully. The Board of Direction has discussed the questions involved at some length and has unanimously decided that the reports should be adopted. But as the measures proposed are somewhat radical they have reported to the Society, requesting that the Society instruct the Board how to act on the two propositions, namely, the separation of the library, leaving only part and depositing certain reports, etc., in such other quarters as may be secured, which are to remain, however, the property of the Society; moving the present remaining library into other rooms and making a lecture room only of this room; and, second, the matter of making certain improvements upon the house, the approximate cost of which will be about $1,000.00. I may say that at the beginning of the year there was a balance reported by the Treasurer of about $1,100.00, and an estimate of the probable expense and income for the coming year, leaving out the rent we have been getting for the rooms we now propose to occupy, shows that we ought to have a balance between $500.00 and $1,000.00. We could, therefore, use the money we had in the Treasury at the beginning of the year to make these improvements, and at the end of the year still have something like $500.00 or $1,000.00 balance. What is the pleasure of the Society regard ing these matters?

Mr. Hirsch—I move that these reports be adopted, and that the Board be authorized to go ahead.

Mr. Swensson—I would just like to ask a question, and that is, where it is proposed to put that part of the library which goes away from here? What disposition is it proposed to make of it?

Mr. Ely—This matter has come up so lately that we can hardly say we have arranged with anybody to take care of these reports, etc.; but from what I have heard and understand I think there would be no difficulty about the Carnegie Library people taking care of them. I might say that turning them over to the Library would not mean that they should be catalogued and indexed as their other books are, but merely kept in trust for us. Probably a better scheme would be to try the Allegheny Library people. That was what we intended to do. But as I say the matter has come up so lately that we have not had time to feel around.

Mr. Swensson—Is it wise to let these records go out of our hands in the first place?

Mr. Ely—I cannot see why it is not. The library is incomplete as it is, and if anybody wants to refer to any file they can always find it at the Carnegie Library.

Mr. Swensson—Suppose it is incomplete; then it has no great value.

Mr. Davison—I think we cannot take this view because, as I understand it, the volumes which the Library Committee proposed to put in trust somewhere have been donated to this Society and it certainly would not be the proper thing for the Society to dispose of those books.

The President—That is not proposed nor asked for by the Board.

Mr. Thomas—In regard to the improvements to the house, I would like to ask a question as to what the Board of Direction contemplates in the way of a permanent location

for the Society. I presume they feel this will be the abiding place of the Society for some time to come.

THE PRESIDENT—We have considered that matter. It will probably be a couple of years at least before anything permanent can be accomplished and, in any event, we have a lease on this house which runs for some three years yet. After considering everything carefully it was decided that the best thing to do was to fix up the house in good shape and make good use of it.

MR. DAVISON—According to your calculation it appears that it will be about four years before anything can be done in this direction. Now I make the calculation in a little different way. We started a little over a year ago to create a house fund. We have about $1,000.00 in that house fund now. We would like to have about $20,000.00 in that fund before we move. One into twenty goes twenty times.

MR. ENGSTROM—To correct Mr. Davison's figures. He calculates $1,000.00 for the year when the committee did nothing; now what I want to know is how long it will take them if they try to do something. (Laughter).

Motion put and carried.

The following persons were then balloted for and duly elected to membership:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
ROBERT J. ARTHUR,	Purchasing Agent, Engineering Dept. of the American Sheet Steel Co., Pittsburg, Pa. h. 333 Hale Street, E. E., Pittsburg, Pa.	S. B. Ely, Harry H. Anderson.
GEO. T. BARNSLEY,	Assistant Engineer, Of Construction, Monon. River Bridge, Wabash System, No. 64 Water Street, Pittsburg, Pa., h. Oakmont, Pa.	Frank M. Ashmead, Charles W. Ridinger.
JOSEPH A. FRAUENHEIM,	Secretary and Treasurer, Iron City Sanitary Mfg. Co., 406 German National Bank Bldg., Pittsburg, Pa.	N. C. Wilson, John W. Landis.
JOSEPH L. HALL,	Engineer, Westinghouse, Church, Kerr & Co., New York, N. Y. Westinghouse Machine Co., East Pittsburg, Pa.	Wm. A. Bole, E. S. McClelland.

HARRY M. PALMER, Mechanical and Electrical Engineer, { Chas. F. Scott, Thos. S. Perkins.
Westinghouse Electric & Mfg. Co., East Pittsburg, Pa.
h. 71 Hazelwood Avenue, Pittsburg, Pa.

JOHN D. SCOTT, - - Manager, - - { W. H. Coster, N. C. Wilson.
Magnolia Metal Co., Pittsburg, Pa.
h. 3352 Perrysville Avenue, Allegheny, Pa.

NORMAN W. STORER, - Electrical Engineer, - { Wm. A. Bole, C. F. Scott.
Designer for Westinghouse Electric & Mfg. Co., East Pittsburg, Pa.
h. 6109 Howe Street, Pittsburg, Pa.

THE PRESIDENT—I desire to announce that there will be a special meeting of the Society under charge of the Reception Committee, which has treated us so nicely this evening at the University Club. Mr. Albree took quite a trip last year, and on April 2d he is going to tell us what he saw and heard.

PROF. KINTNER—If new business is in order, I would like to move that a committee be appointed to investigate and report upon the matter of the metric system now pending before Congress. I believe this should be thoroughly discussed and, if possible, some resolution be adopted and addressed to our representatives in Congress. In order that this matter may be brought before the Society in the regular way, therefore, it seems best to have a committee appointed. I therefore move that three members be appointed by the Chair to take this subject in hand and report.

MR. ENGSTROM—I second the motion.

MR. DAVISON—Did we not have a committee before on this subject?

THE PRESIDENT—I believe the Society took action on this question some eight or ten years ago. I am not certain just what they did.

MR. SWENSSON—I believe there is a resolution on the books stating that we should use the metric system and nothing else in our papers, and I believe there was a fine to be levied against members who did not use it.

THE PRESIDENT—I guess that is right. I read the first

paper after that resolution was passed and employed the metric system, but nobody seemed to know what I was talking about. You have heard the motion, gentlemen.

MR. LENT—I would amend, asking the committee to make a preliminary report so that the members of the Society may know beforehand definitely what report they intend to make.

Motion as amended carried.

THE PRESIDENT—I appoint on this committee, Prof. S. M. Kintner, Mr. W. A. Bole and Mr. Chas. Hyde.

MR. SWENSSON—Mr. Camp has just reminded me of something that I saw in the paper. Professor Brashear has appeared before the Committee of Congress and spoken on the metric system. Now is it wise to have this Society go over it again. I tell this for the benefit of the committee that has been appointed.

MR. WILSON—I have my report of the last Reception Committee's expenses made out, but unfortunately I left it in my office; but I can give you the principal items as I have jotted them down here. This refers to the last banquet of the Society at the Schenley:

Expenses, Hotel Schenley	$ 932.80
Menu, (cards)	118.00
Flowers	70.00
Music	50.00
Cards	3 75
Postage	3.00
	$1,177.55
Amount received for tickets	1,151.30
Showing a deficit of	$ 26.25

We did not go into the scheme with the idea of making any money, but simply tried to give the best banquet we could with the funds in sight. Had all the members who promised to purchase tickets done so we should be able to return to the Society about $15.00 on account of this banquet instead of showing a loss of $26.25. Another thing, on the last smoker

we had, there was still about $23.00 which had been subscribed, but which has never been paid in. If all these subscriptions had been paid in we would have been able to return to the Society about $48.00. There are at least three men who turned in lists of names of men who failed to turn up, although, of course, we had to pay for their places just the same as if they had been there. I think this will give an idea of why we are short $26.25.

MR. CAMP—Knowing the hard work which Mr. Wilson and the rest of the committee has done, I think it would be fitting that the Society should make up this shortage out of the general funds.

DR. STAHL—I make a motion that this be referred to the Board of Direction.

Motion carried.

MR. HIRSCH—I think the Society is very much indebted to Mr. Wilson and his committee, and I move that the thanks of the Society be voted Mr. Wilson and his committee.

Motion carried.

THE CHAIRMAN—We will now listen to the paper of the evening, entitled "Automobiles," by H. P. Maxim.

AUTOMOBILES.

BY HIRAM PERCY MAXIM.

It is a singular fact that even among engineers the automobile is not generally well understood. Probably the least well understood feature connected with the automobile is its field, or just where its place among modern apparatus really lies.

MR. H. P. MAXIM.

The public generally think of an automobile as a kind of toy intended more for recreation and sport than anything serious. In the minds of a very considerable number of people the automobile is looked upon as a fad, comparing with the roller skate and the bicycle.

It cannot be denied that there is an automobile fad to-day. The indications point to its ranking any previous fad in history, which may make it a matter of considerable commercial importance. But this is not the whole story. To tell the whole story and to show the automobile's real place in the world there is perhaps no better way than to recite the results of some examinations and tests which have been made as a guide in the application of the automobile to certain existing trans-

portation troubles. This data has not before been collected, to the knowledge of the writer, and, in addition to explaining the real place of the automobile, it may also act as more or less of a mile-stone in these early days of its development. It is as follows:

Urban or city transportation, or at least that part of it which is to-day having trouble with its motive power is divided into four classes:

1st. The transportation, in a private vehicle, over irregular routes, of usually one but possibly two passengers engaged in such service as the daily visiting of physicians, contractors, collectors, inspectors, and similar business men.

2d. The transportation of one or more passengers over irregular routes in a hired vehicle driven by a hired driver, or, as is better known, cab service.

3d. The transportation of several passengers by regular omnibus lines on city streets which are prohibited to street cars.

4th. The collection, transportation and distribution of miscellaneous, city and suburban merchandise.

In every one of these services the horse has gradually become unsatisfactory as a motive power. The reason for his inability to prove satisfactory now, when he has been satisfactory for centuries past, is of course due to the changes that have been made in motive power in all other branches of transportation. If it were not that the steam railroad and the electric street car had set standards which other forms of transportation must meet, there is no doubt that the horse would have continued to give satisfactory service in the work we are considering.

Taking up the divisions of city transportation as they have been given, their general characteristics which show the cause of the trouble are as follows :

1. Private Vehicles for One or Two Passengers.

From mileage tests and examinations of business carriage service in several large cities it has been found the total mileages made per day run somewhere about as shown by curve A (Figure 1). The average horse is said to be able to go not over 15 miles every day in city service, if he is to last any reasonable length of time. In regular service it is seen that 85% of the carriages go more than 15 miles in a day. By horse motive power it is then plain that either rapid depreciation must be suffered or the motive power equipment duplicated. Either case produces expenses which are the beginning of the unsatisfactory performance.

This question is, however, in practice not the only one that is troublesome. In every-day work the horse as a motive power needs consideration which is inconvenient. He is not easily cut out, so his power cannot be accidentally turned on. He requires protection from cold and heat. He cannot, without injury, accept an overload for an interval and then stand under no load for a longer interval. He has ailments which cannot be investigated with a two-foot rule and cured by a renewal of the affected part, and he is limited in speed on long runs where speed is safely possible and most economical.

To substitute a mechanical motive power in this service a few more of its characteristics are required. Especially is this important in the determination of the most suitable of different forms of motive power.

Curve B shows, as nearly as this service can be plotted, the maximum mileages before return to the home point. It is found that only 12% of all vehicles in daily use run more than 20 miles before returning home. Likewise, only 18% run 18 miles or more before returning. In other words, no less than 82% run less than 18 miles before opportunity for some form of recharging occurs.

The length of time at home before starting again which would be admissible for recharging was then investigated, as it of course would be the important factor, taken in considera-

tion with the mileages, in determining the kind of motive power most suitable.

It was found that 85% of the vehicles laid over at the home point a total of 2¼ hours or more during every day's work. The remaining 15% either laid over an hour or not at all, probably due to eating the noonday meal at home and immediately going out and remaining out all the rest of the day, or picking up the meal at unknown points.

Fig. 1. Electric express car. Miscellaneous express and freight is transferred between long distance points in these cars.

Investigation was also made into energy expenditure per ton mile or "wattage," as I have termed the value. These measurements were made by mounting a recording watt hour meter in an electric automobile, and either following around the vehicles, being observed from the start in the morning until the finish at night, or by putting the automobile directly

into the actual service itself. Mileage and stop readings were of course also taken. It was found that in fairly level cities, such as New York, Hartford, Chicago, Cleveland and Philadelphia, the service wattage bore a relation to the wattage on a level asphalt road, called "Level Wattage," of from 1.10 to 1, to 1.13 to 1, or in other words, an increase of from 10% to 13%. In Pittsburgh the figure was found to be from 20% to 25%, due to the hills and bad pavements.

With all this data, it becomes easy to determine the motive power most suitable for the majority of the work.

If in only 12% of the cases the total mileage per day exceeds 30 miles, and in only 18% of the cases the maximum mileage before return to home point is 18 miles, and in 85% of the cases, the total time of lay-over at the home point is 2¼ hours or over, and the service is one where the business man, preoccupied and hurried, does the driving, then it is undoubtedly safe to say that for 75% of this service, electric motive power is best, and will be ultimately used.

For the remaining 25%, with its short or entire absence of lay-overs, or where the mileages are beyond the practical field of the electrical equipment, the engine propelled system is best and necessary.

For the entire 100% of the service we furthurmore see that the automobile, even as it exists to-day, is able to better do the work than is the horse.

2. *Private vehicles for one or more passengers.*

This is, of course, the cab. The cab is really an enlarged type of the small private vehicle just discussed, but furnished with a hired driver. It is distinctly a business vehicle, and though public nominally, is really private while in the employ of the passenger.

The service of the cab is found upon investigation to be very peculiar. Its characteristics are not susceptible of plotting, as in the case of the small business carriage. It seems to

have a high caste and a low caste. In its high caste form it demands, regardless of cost, the maximum of comfort and convenience in the transportation of a passenger, from the very door of his starting point to the very door of his destination. In its low caste form, it demands the lowest possible rate of fare, and only a moderate degree of comfort.

In the high caste form the horse is fairly satisfactory, though his expense due to depreciation reduces the possible earnings. This is the principal form in which cab service exists to-day.

In the low caste form there are but a very few cabs in existence. What there are—the Boston herdic being a good example—are entirely unsatisfactory in comfort, speed, distance capacity and cleanliness, owing to the very rigid economies necessary where the horse is the motive power.

The mileages of both classes of cabs have been found to be large in the aggregate per day, as may readily be imagined, since mileage is nominally earnings. The lay-overs are frequent and at times long, but they are usually irregular.

The wattage, or energy expenditure, has been found to be very considerably higher per ton mile than would ordinarily be expected. This is due to the presence of the hired driver, and the less careful manipulation the vehicle receives at his hands than it does at the hands of the owner. The cab driver is always interested in hurrying, in order to earn possible reward in the form of fees, and has, up to the present time, no direct interest in keeping down wear and tear and energy expenditure. The owner of a vehicle, the driver usually in business carriages, on the other hand, is financially interested in both.

In practice it is found that the service wattage averages an increase of approx. 30% to 35% over the level wattage.

When it comes to motive power, the high caste service is interested only in the electic, and that only as a means of getting greater mileage per day, better speed in trips and consequently more trips in a day, and lower operating expenses.

In New York over 200 automobile cabs are in daily service in this high caste work. All of them are electrically propelled.

They have unquestionably provided at least some of the improvements demanded, for we find them a recognized factor in the city's transportation problems. The strength and permanence of their position may be judged, when it is stated that they are used for daily transportation, because of their ability to give a maximum of privacy and comfort, and to consume less time than would be the case by any other transportation available.

When we come to the low price cab, where the governing law is the survival of the cheapest, the conditions are different. The horse has been unable to make possible a cheap cab, which is satisfactory. As things stand, we usually have nothing that is publicly available between a one dollar, or more often a two, three, or even four dollar carriage, and a five cent place on a street car. Every night in the year, in most of our large cities, this unsatisfactory graduation in the scale of transportation facilities, is a cause of extreme discomfort, and oftentimes suffering. As an example, take a rainy night in Pittsburgh. Hundreds, and more frequently thousands, of people returning from places of amusement are compelled to crowd into a street car filled already to overflowing with steaming, wet humanity, and be pushed and elbowed in the closest contact with we know not whom, for half an hour, and finally deposited, in probably 75% of the cases, a quarter of a mile from their homes.

A finer graduation of the scale than is represented by 5 cents and $2.00 would be very acceptable to a great many of these people. But the horse cannot supply this finer graduation and make it pay. The substitution of a mechanical motive power changes this state of affairs, however.

As an indication of what is possible in cost, per ton mile with the prime mover propelled vehicle, the following is of interest:

In the ordinary gasoline engine propelled automobile of to-day, the level ton mile is easily accomplished on .066 gallon of gasoline. If the service wattage is 25% over level, the service gasoline consumption per ton mile would be .083 gallons. If the daily mileage is 40 and gasoline costs 13c per gallon, and the cab and load weigh 2,000 lbs., the cost of fuel for the entire day's work would amount to

$$.083 \times 40 \times .13 = \$\ .43.$$

The only additional vehicle expenses would be lubrication and depreciation. These could be enormous and out of all probability, and yet leave the cost far below what would be possible with the horse.

With an electric system, the power being originally generated by a prime mover, the many conversions of it makes it usually cost more per ton mile than is the case when the prime mover is directly upon the vehicle.

On this basis it would seem that the engine propelled automobile would be able to best withstand the workings of the law of the survival of the cheapest.

With such a motive power driving an automobile cab, several steps become possible of insertion in the graduation between 5c and $2.00. I firmly believe such an automobile is not only possible to-day but inevitable in its coming. It will make available to us a means of transportation which in comfort, convenience, speed and rate of fare will cause 75% of us to adopt it for all evening and a certain share of our day traveling.

3. *Public Vehicles for Several Passengers.*

This is the omnibus. Its service consists principally in a regular schedule of omnibuses operating on streets or routes not provided with street cars. In some cases street car lines are not economical, and in others the streets are prohibited to electric cars, yet in each passenger transportation facilities are imperative.

In almost every one of these cases the limitations of the horse have long been the cause of extremely unsatisfactory service, and demands for improvements in motive power most insistant.

The characteristics of the service have been found to be easily met by automobiles in every case, and several lines are being equipped at the present time.

The aggregate mileages per day per bus are, as may be expected in any continuously running vehicle, relatively high. This is not of so much importance, however, as in this service the vehicle periodically passes the home point. The maximum mileage before return to home point is of greatest importance, and is the factor which determines the form of motive power most suitable.

This mileage is found to vary greatly. In some cases it is 3 miles and in others 30 miles.

The lay-overs at the home point are invariably short, owing to the desire to keep the number of buses down, and the consequent necessity of keeping them continuously running.

The wattages have been found to depend upon the number of stops and starts and the nature of the traffic on the streets over which the routes run. Where the passengers picked up and dropped are few per mile and the traffic conditions open, the service wattage rarely is over 20% increase over the level wattage. Where, however, the passenger stops are frequent and the traffic conditions crowded and tending to increase the number of slow-downs and accelerations, the increase amounts to much higher figures. On Fifth ave., New York, the wattage averages in the vicinity of 50% increase, while in winter, during a snow storm or before the avenue has been cleared, it amounts to 150% and over.

The motive power almost exclusively used to date is the electric. It is, of course, limited to routes having mileages between returns to home point within the practical possibilities of the batteries. The batteries are changed each time of passing

the home point, or every other time, as the case may be, by mechanical elevators and transfer apparatus, a freshly charged battery being substituted for the discharged one.

In all of these cases where the installation has been carefully done, it has been found that the automobile bus was infinitely superior to the horse-drawn one, and important future development seemed inevitable.

Where, however, the routes are such that the product of

Fig. 2. A modern merchandise distributing equipment at sub-station

the mileage before return to home point and the service wattage per ton mile is beyond the practical limits of the storage battery, or where battery changing and charging facilities are not practical, the electric system is not suitable, and the engine propelled vehicle becomes best.

Gasoline engine propelled omnibuses are in use in Europe in several places, and steam buses have been frequently used in

this country. All have not been successful from a financial standpoint, but every one has been of immense success as far as the improvement of transportation facilities went. The financial failures we may take as defects in handling more than defects in the principles involved, as what has been accomplished by the automobile bus has been too much of an improvement over horse service to be overlooked or forgotten.

4. Freight Carrying Vehicles.

As already stated, this class is divided into three branches. As far as motive power is concerned they may be taken together, as their work is near enough alike to admit of it.

The work to be done is the collection and distribution of relatively light miscellaneous merchandise, or as it is better known, "express matter." There is no more difficult service for horses. The points of collection are scattered all over a city, as are also the points of distribution. It makes no difference whether it is the same matter that is distributed that was collected, as the work of transportation is the same.

The aggregate mileages per vehicle per day have been found to vary considerably. This is due to arbitrary business reasons. For instance: the Pittsburgh Express Co., in Pittsburg, and the Metropolitan Express Co., in New York, collect at and distribute from central stations located in different parts of their respective cities, and have arrangements with the street car companies to do the distance transportation between these points in electric express cars running on the street car tracks. Their wagon mileages are consequently relatively low.

On the other hand, the Manhattan Express Co., in New York, a local and suburban company, and the Adams and American Express companies do all their city transportation by horse wagons. In a large city this makes the mileage high. An idea of the mileages is obtained by the following, made from careful tests: In the down town district of Pittsburgh,

where the principal purchasing, and therefore collecting, is done, the average mileage of wagons engaged in express work is 8¼ miles per day. The maximum of all those measured is one engaged in both distributing and collecting, and runs from virtually the Pennsylvania Railroad station out Fifth ave. and Forbes street to the Hotel Schenley, and then back over Herron Hill. The length of this run is 9½ miles. One trip per day is made.

The minimum is one confined to the down town district, and is 7 1-16 miles per day. This seems surprisingly low, yet is a full day's work. It is doubtful if more than 15% reduction in this time could be effected, no matter what the speed of the vehicle, as most of the time is taken in loading and working slowly through the other street traffic.

In East Liberty, the wagons doing principally distributing run an average of 19½ miles per day. In New York, wagons of the larger express companies doing distributing and collecting between branch offices average 30 miles every day, the maximum measured being 40¼ miles and the minimum 16 miles.

Not enough uniformity exists to make it practical to plot general tendencies, as can be done in the passenger vehicle service.

The lay-over characteristics are fairly uniform, and such as to immensely simplify the application of mechanical motive power. In the cases of collecting wagons in the down town districts of Pittsburgh, for an example that can be judged fairly well, the total hours per day lay-over per wagon at the home point averages 2¼ hours. The maximum measured is 2 hours and 56 minutes, and the minimum is 1 hour and 30 minutes.

In East Liberty, distributing wagons lay over an average of 2 hours and 10 minutes at the home point. In New York, wagons doing 40¼ miles every day (requiring three changes of horses per day to do it), lay

over a total of 3 hours at the home station and another hour at some of the important sub-stations, or 4 hours where recharging would be convenient as not. The minimum lay-over in New York express wagon service can be taken as 2 hours during the day; still a time enabling 75% per cent of a storage battery's complete capacity to be returned to it.

The wattage increase in this kind of service is invariably found higher in the short mileage routes than in the long ones. In the down town wagons in Pittsburgh, for instance, the average increase over level wattage is 69%. In the short down town routes of New York, it is, in cases that have been measured, 75%.

In East Liberty the average is 25%. In long runs in New York, it runs about 29%. The reason for this vast increase of the short over the long, is the almost universal bad stone paving in crowded down town districts, and the universal asphalt or good stone paving on long avenues. It has been found that accelerating a heavily laden wagon over pavements having bad holes, hollows and car tracks, requires many times the energy expenditure that is necessary on a clear stone pavement, filled with small and uniform hollows, or yet better, an asphalt pavement. The effect of these pavements on horse flesh depreciation is not appreciated even by express companies.

An interesting indication of this is shown by the fact that even with Pittsburgh hills the wattage is less than in New York. This is due to more frequent use of asphalt in Pittsburgh in the down town districts, and the almost universal asphalt in the outer districts. In tests the writer has made of express routes, including Third ave., the Bowery, Peck Slip, South st. and Fulton Market, in New York, where the paving is the worst the writer has ever seen, the service wattage was found to be 78% over level wattage. This was almost entirely due to the dense traffic and the continuous acceleratings from almost standstills. For some unfortunate reason, the

pavements are always the worse the denser the traffic, which aggravates the power expenditure trouble. With no horses' feet to provide for, these pavements could be good, and the present waste of power would be almost all saved.

Altogether it is seen that in this express service the conditions are favorable for the successful performance of mechanical motive power, even as we have it developed to-day. Especially would mechanical motive power show to advantage in what we called the long runs, owing to the ability to make

Fig. 3. Electric automobile express wagon in service.

speed. It is in these runs that the horse suffers most, both in hot and in cold weather, for it is here that speed is most wanted to compete with rail transportation. Long lay-overs being universal at both ends of nearly all runs, power is easily recharged, and only a moderate surplus is necessary, even with winter snow.

Up to the present time the motive power almost universal where automobiles have been used in this service—and

there are hundreds at work to-day—has been the electric. Only in a very few cases, comparatively, has gasoline or steam been used. Where they have it is usually in the distribution of purchases from private stores.

In all probability in express service, gasoline or steam, as the prime mover systems, would be able to show less saving in cost of transportation per ton mile over electric system than is usually the case. This is due to the wholesale character of everything, when large numbers of vehicles are operated from one point, as would be the case in express service. Power would be used in large enough quantities to pay to generate it from large units, which are very much more efficient than the engines of an automobile could ever hope to be.

Battery repairing and renewal would be done on a wholesale scale, which would materially decrease this most expensive feature that the electric system has.

For these reasons it seems unquestionable, when it comes to the question of motive power for transportation of express matter, that the electric system offers the greatest number of advantages, and will for some time to come, be the principal motive power used. That it will always be so is not plain, as the law of the survival of the cheapest per ton mile, other things being equal, will be as inevitable in this as is the law of the survival of the fittest in nature.

This completes the recital of the examinations and tests that have been made into existing transportation problems and the consideration of the suitability of the automobile for their improvement. In such a recital it is not possible, without taking up too much time, to go into the designs of existing automobiles, and study their detail suitability for work of the kind described. So an automobile including the best of all designs has been assumed.

From this recital it must be conceded that the mechanically propelled vehicle, independent of fixed tracks, is a development resulting from the need of better transportation, rath-

er than because of any fad. Our cities have already spread to areas which make the irregular transportation of passengers and merchandise over them most difficult, and the continued development of the prime cause of it all—the electric street car—is daily increasing the difficulties. The automobile comes as a successor to a part of the work of the horse, just as the electric street car came as a successor to part of his work. From the very nature of our civilization it becomes an absolute necessity. The mechanically propelled street vehicle is as inevitable as was the mechanically propelled boat, railroad train and street car, and we might as well include such institutions among our fads as to include the automobile. When it comes to their manufacture, where we will build one for pleasure, sport, or fad, we will build one hundred for serious work.

DISCUSSION.

THE PRESIDENT—In reading over the advance copy of the paper which Mr. Maxim has just read, there were two points which struck me with great force. One was that the way in which I had regarded the automoble, the way in which I had heard the subject discussed with a great deal of interest—and almost vehemence by some of my friends who are automobile enthusiasts, was hardly mentioned at all nor included in the classification of its uses; and that is, its use as a pleasure vehicle which I should think constitutes about nine-tenths of the service to which the automobile is put at the present time, but which is almost entirely disregarded by Mr. Maxim.

The second thing I noticed as not being fully treated by Mr. Maxim is a point which I have heard discussed by my friends and which seems to me to excite the greater proportion of the controversy on this subject, is the question as to whether the automobile should be electric, steam, or gasoline. Mr. Maxim, however, has not taken this up to any extent, but I should say has made this feature one-tenth instead of nine-tenths.

I presume, however, that there are others who may be called upon to give this point due prominence.

A gentleman who is connected with automobile work but who is unfortunately not with us this evening, stated to me within the last two weeks that the horse for express service—local express service—in ten years from now would be used only as a method of advertising. This subject is one of much interest and the paper is now open for discussion.

MR. HIRSCH—I would like to ask Mr. Maxim a question. He speaks of the use of electricity as the present and coming motive power for automobiles but states "that it will always be so is not plain," etc., etc. I would like to ask him what other power might be used instead.

MR. MAXIM—I think electricity as a motive power will be used first for express service because we can get the maximum reliability from it. In making the substitution of a mechanical motive power for the horse in express service to-day we have to get something that will work pretty nearly right the first time. As far as reliability goes we might say that electricity is almost fool-proof. We are dealing with a revolution here. We have to throw down a lot of strong ideas and prejudices, and it is my conviction that electricity will take the field in express service first because we can make the electric automobile so that it is almost independent of any skill on the part of the driver. The driver need only steer and apply the power and take it off. There is no other form of motive power available yet in which such simple operation is possible. There are two other motives powers in use to-day. The gasoline engine and the steam engine. We probably stand a better chance of getting an absolutely automatic motor with gasoline than we do with steam. We can now produce a horse power hour cheaper with it than with any other motive power suitable for a vehicle. We can probably get the H. P. hour for one-half what we can get it with a steam plant on the same vehicle. It seems very doubtful whether we shall ever get a steam plant

entirely automatic—one which it will be safe to make automatic. Therefore, just as soon as we can produce a gasoline motive power equipment which requires no more skill to drive than the electric machine does to-day, where engine power counts for anything, the gasoline machine may be better than the electric. I do not believe that steam has any chance whatever. That is why I say it is probable the electric machine will not always have the lead. In express service, where they cannot afford to have anything unreliable, the gasoline may eventually give the electric automobile a hard rub. But I have been unable to see any chance in that service for steam.

Mr. Newman—In reading over the advance copy of this evening's paper, the same thing as mentioned by Mr. Scott in connection with pleasure automobiles struck me very forcibly, and I think there are a good many people inquiring as to the future of automobiles and who want to know whether they will be permanent or not.

The basic value of any proposition depends upon its commercial importance and, naturally, the first question which comes to the engineer and capitalist is what conditions exist which will make a market for automobiles and will create a desire in the public mind for their use. Mr. Maxim told us that the desire to improve upon the present system of transportation has brought about the advent of the automobile, and that it is being pushed to perfection by existing conditions of road transportation, which was brought to our notice by the work which the steam and electric cars have done in bettering their respective methods of transportation. The passing of the horse is not due to the immediate introduction of the automobile, as many people would suppose, but I think it began with the time when mechanism were first introduced into commercial and industrial life, and that the automobile is only the fourth or fifth step in the ladder of progression. I am a great believer in the future of the electric vehicle and in this connection it might be well to say a word or two about the comparison of apparatus. At the

first automobile shows held three or four years ago the number of electrical vehicles on exhibition were far in excess of the number of either steam or gasoline machines. At the Madison Square Show last fall, held in New York, there were only three electric vehicle companies represented. Three weeks ago in Chicago the number of electric vehicles represented about one-third of the entire exhibit, or an equal proportion with the steam and gasoline machines. The sentiment around the hall was that we were just on the threshhold of expansion of the electrical vehicle industry especially in the line of commercial conveyances. The problems involved in this branch of electrical engineering are different from almost any other, with the possible exception of the street railway, but in automobiles we have modern street railway work in its worse form. The main trouble with electrical vehicles so far has always been with the storage battery, and I believe we can say that the greatest line of improvement will be in this direction. I saw a statement a few years ago which was attributed to Mr. Edison as a remark made concerning the storage battery. He said, "the darn thing is wet." I think the storage battery has been the cause of much criticism from engine people who unfortunately are not familiar with the facts and willingly unaware of the number of failures with gasoline and steam machines. The engine people have tried in the past to sell their machines by picking out the flaws in the electric type and have succeeded. The steam vehicle I believe is only a temporary affair and to take care of the present desire for a light pleasure vehicle. My own judgment is that the vehicle industry of the future will be the manufacture of the style of machine Mr. Maxim speaks about, and since it will consist in the manufacture of vehicles for commercial use, it will be the electric automobile since it has too many good points to allow its weaker ones to cast it aside. It is quieter, easier controlled, less apparent danger, no heat, odor, or vibration. These are the points which appeal to the purchaser. Its simplicity, efficiency, reliability and flexibility of the motor, are

points which appeal to the engineer. In the endurance run from New York to Buffalo last September, we had a pitiful exhibition of breakages and necessity for repairs every 50 or 75 miles. There were no electric rigs in that test, but in looking over the data of the run I am sure that our present electric delivery wagon could have gone through that test if it had been allowed the same time for recharging batteries as was taken by the steam and gasoline machines in breakdowns and stoppages for repairs. The steam people in many cases had burned out boilers because they had to pay so much attention to the condition of the roads that they could not properly watch the steam gauges, and the condittion of their fires. The gasoline people had carburators, sparking devices and cooling systems to attract their attention. With the standardization of apparatus, such as was brought about in the perfection of the electric railway, we may expect to see many changes in vehicle construction—there will be a systematic manufacture, a reduction in cost of production and better parts made by specialists rather than "jack-of-all-trades," making a complete rig.

Mr. Engstrom—I would like to ask a question. One of the speakers has mentioned the absence of odor and vibration in the electric vehicle; also, that it makes less noise. But I have noticed this difference. I do not know why it is and would like to have it explained. The electric vehicle seems to me very cumbersome. The little steam and gasoline runabouts appeal to the eye. It seems to me they are more graceful, light and dainty. Now is it necessary to have the electric machines so cumbersome and heavy?

Mr. Maxim—I think that subject has more weight than anything else. [Laughter.] I believe you will find that the majority of people think that the vehicle will suit them best which looks best on the outside. Now I have had a great deal of experience with express people and other purchasers, and every one of them, without a single exception, say exactly what you do. But what is really desired is the automobile which will

earn the most money. I believe the lightest automobile in existence to-day is an electrical one—taking all the steam and gasoline machines on the market and in practical operation into consideration. In regard to the steam and gasoline automobiles an illegitimate amount of effort is being made to make them sell. The steam vehicle is built regardless of future requirements, regardless of how satisfactory it would do regular work. It don't take a man very long after a steam machine has been delivered to him to learn that it has been built to sell. I should estimate that in a steam carriage 90% per cent. of its good qualities you see the first time you look at it. In the gasoline carriage you see about 10% of its good qualities, but you find the others when you get it home. In the case of the electric machine, as far as cumbersomness goes, it has been proven by several makes on the market today that it can be made the most graceful of any form of vehicle. Speaking again of the pleasure vehicle, with a pleasure automobile you have to coax people to buy. I would be very sorry indeed to be in a business which depended upon coaxing. But when you can produce a thing which is better and which will enable men to earn more money, or better meet competition, you have something which you can drive him to buy. When you are making a vehicle which simply appeals to a man's idea of pleasure for a day or two I do not think you are in a permanent business.

MR. FLANNIGAN—Referring to the flexibility of the motor, I judge the idea is worth bringing out that the gasoline machine is more liable to "lie down" under overload than is the electric machine. For instance, suppose it comes to a grade not contemplated when starting out, it would be more likely to stall than the electric vehicle.

MR. MAXIM—I do not know that I understand exactly what you mean. I believe Mr. Newman made the statement that the electric motor was more flexible than any other form of motor.

MR. FLANNIGAN—If a gasoline automobile is moving

along the level and working at its maximum load, would it not be more liable to stall if it came to a grade.

Mr. Maxim—Yes, that would certainly be the case. But that is a case of bad design which would apply to other vehicles as well. If a machine is running at its maximum power on the level when comes to a grade something is bound to happen.

Mr. Flannigan—Yes, but in the ordinary use of electric machines, they are capable of developing an overload for a short time.

Mr. Maxim—If a gasoline automobile stalls on a light grade it is because it is away below the engine power it should have. And in general the gasoline automobile is away behind in engine power. In developing the electric machine we have the experience of the street railway art to work on. In designing the gasoline machine we have not this experience. A gasoline engine may be designed, however, as flexible as the steam engine.

The President—We have with us this evening a man who has just consented to put in an application for membership. He is said to be well up in the automobile business, and if Mr. Reuben Miller will favor us with some information on this subject we will be obliged.

Mr. Miller—I consider myself at a great disadvantage in the manner of my introduction. I have applied for membership, but had not expected to say anything to-night, and can hardly speak to advantage on automobiles or anything else. I have had the pleasure to-night of meeting Mr. Maxim for the first time, although in a business way I have known of him for a good many years. I think I have had some practical experience in running automobiles. I have owned two of different motive power, each of which I believe Mr. Maxim to be responsible for. One of them, I was going to say, I pushed home, but I didn't, because I couldn't. I wanted something a little stronger, something that would do more work. I wrote to the general sales agent of the compar y where the machine

was made to take up this question. I wrote him in very glowing terms and stated that it was the best machine I had ever had. This was a short while ago when we were having zero weather. Mrs. Miller went out the next day with one of the machines which is her own and which she uses all the time. The machine got part way up a hill and then seemed to go wrong. It appeared willing enough to go, but it would not go straight very well. It was a double-motor electric equipment and the electrical connection of one motor had been broken. Some Italians on the Boulevard finally had to turn the machine around. It was only two or three days after this that the other machine—which is a gasoline machine—was being brought to town late in the afternoon. Something happened. It was a small trouble. A small piece of porcelain cracked off the insulation in the sparking plug and became loose inside of the stuffing box. No one could tell what had happened. There might have been a dozen things wrong with it, the inlet valve might not have seated properly, the electric battery might have worn out, something might have gone wrong with the induction coil. You will remember I had just written the sales agent, telling him what a tip-top, capital machine it was. It stopped on the Boulevard back of the Hospital before they got down town, and we had to get another machine to haul it in. In the meantime much damage had been done by the natural consequences of freezing. However, I am ready to say again to the sales agent that the machine is a good one. But my experience only emphasizes the fact that you cannot know too much about automobiles, especially gasoline automobiles. As long as they operate successfully they are all right, but when they do go wrong it is frequently difficult to locate the trouble promptly. When they go right they are certainly a great deal of pleasure. I believe with Mr. Maxim that the field of business is the ultimate field for the automobile.

The automobile is similar to a horse in many respects. I

have been asked by friends what kind of an automobile to get. I would rather be excused from answering a question like that any time and have thought that the best reply to give—if the inquirer happened to be fond of horses—was to draw the comparison, whether he was fond of a lively horse, or a fast horse, or a horse that a lady could drive, which ever he liked best, that was the kind to get.

This year there are several good automobiles on the market which almost anybody can run with the mimimum of trouble. The gasoline automobile is being developed very fast. The electric vehicle has not developed so fast because I believe that it has about reached its ultimate development outside of the storage battery. We will get very little further outside of development in the storage battery in transmission of power by the electric machine. We have worked the electric machine down until there is little left in the way of development. In the gasoline arrangement we have multiple cylinders so placed as to reduce vibration to the minimum. The chief draw-back to the gasoline machine from a pleasure standpoint is that its flexibility depends to a great extent on changing the gears, that is, in order to secure variation in speed and power. We can change the speed and power by changing the point of ignition and by throttle. Both methods are used, separately in some machines and together in others. I believe, however, that the typography of the country and the better condition of the roads will have a great influence in the development of the automobile; and where these conditions are favorable the electric machine has a big field before it. I believe that the condition of the roadbed will have a greater weight in future development than any other one thing. We have the men, we have the means, and we have the demand for an electric automobile, but until we get the roads for them to run over we cannot use the electric vehicle on account of its weight per units of power. We must either have the good roads or we must get a storage battery of lighter weight and better adapted for continuous service.

MR. WADSWORTH—I have been very much interested in what has been said this evening and simply question two statements that have been made, one by Mr. Maxim and the other perhaps by Mr. Newman. Mr. Maxim, I believe, stated that the electric automobile was the lightest in the market to-day. It seems to me that this statement is a little too comprehensive. Take the same structure and frame and comparing the battery weight and the rest of the vehicle, the electric slow-speed motor vehicle is heavier—unit for unit—than either the steam or gasoline engines. So I do not see how it is possible for an electric automobile of a given power to be lighter than either the gasoline or steam-driven vehicle.

Second, the statement has been made that outside of electricity, there are only two other motive powers to be considered in this connection, viz., the steam engine and the motor driven by gasoline or explosion engine. That, it seems to me, is narrowing the field a good deal. Two other motive powers might be mentioned, one of which has been tried on street cars, viz., compressed air and carbolic acid. The statement has also been made that the electric machine has been proven the most reliable. In connection with this point I have wondered why it is that so far no electric automobile has ever been entered in a race. I do not mean to say at all that the vehicle chosen by racing men should be taken as the standard. But after all that vehicle is chosen which they consider most reliable.

MR. MAXIM—I heard a man say once that the general public's idea of the different kinds of automobiles reminded him of fishing for trout with a derrick. Now you cannot use an electric automobile for racing or for touring over the country any more than you can use a derrick to fish for trout. It is not built for that purpose. Where we have got to go a distance in excess of the practical limitations of the storage battery the electric machine is absolutely helpless. I say that about 75% of the automobiles that will be used to earn money will be electric because the distances they will have to travel before they come to

a place where they can be recharged are easily within the limitations of the storage battery. We can get a vehicle that will go a longer distance without stopping, at a higher speed by using the gasoline engine for the motive power. Ninety per cent. of the racers in use to-day are gasoline machines. We almost never hear of an electric automoble in a race. We seldom hear of the steam machine in a race, because of the large consumption of fuel and water.

Now, so far as the lightest machine is concerned, I believe the Baker runabout made in Cleveland is the lightest automobile built for pleasure purposes to-day. It weighs 750 pounds, carries two passengers, its advertised mileage is 40, advertised speed 10 miles per hour. So far as I know this is the lightest automobile that can be considered practical to-day.

MR. NEWMAN—I believe I remarked about the reliability of the electric vehicle and also spoke of the flexibility of the motor. In this connection I was speaking of the apparatus in general and not of the storage battery. Then I also mentioned that in the New York-Buffalo endurance contest I was quite sure that one of our present electric delivery wagons could have gone over that 500 miles if the same time had been spent in recharging the vehicle that the others spent in repairing. The record of the test with the time spent in making repairs, stoppages, etc., was published by the racing committee, and with some data on hand in regard to tests with delivery wagons, we figured that it would have been no trouble at all to have gone the entire distance at a speed of 11 miles per hour. As far as reliabilty goes the endurance contest gave rise to a great deal of discussion as to whether it could properly be called an endurance contest. Some makers entered two or three machines; the boiler would burn out on one of them and be replaced from the other machine, etc., etc., so that at the end of the route it was hard to tell what machine it was, being composed of the parts of several. Now I only know of three or four rigs that went through the test without any repairs what

ever, I believe three gasoline machines. One was a French make. They went through that test and got "A" certificates which meant that they averaged 15 miles per hour when running. The American machines did not make any pretence at speed like the French machines. That just shows you what rigs went throught that contest could be called perfectly reliable. And on that score I think the electric vehicle is more reliable because you would simply have to connect up to a 110 volt main every fifty miles.

Mr. Miller—Speaking of the electric automobile never having been entered in a race. I think I remember there was such a machine entered in a race at Long Island by Mr. Riker and it did very creditably. I believe it made the mile in either two or three seconds over the minute, which of course is out of all reason for the electric machine ordinarily as made to-day. This machine was especially made for this occasion, and was towed to the starting point and towed away.

Mr. Newman—I know of an electric vehicle that was run in a race in Chicago. It was a double motor equipment and geared especially high. It made the mile in a little more than a minute on that track.

Prof. Kintner—In reading over Mr. Maxim's paper there was one point in connection with the possible field for cab service that struck me forcibly and that was to provide a fare between 5 cents and $2.00. I happen to remember some data of a test made by Mr. Fliess in New York in connection with some delivery wagons in service at that point. He figured that it was possible to deliver 100 pounds per mile for 5 cents, and on that basis it seemed to me possible to deliver passengers three or four miles for 50 cents. Included in this 5 cent figure is the cost of power, hire of driver, etc., etc., and depreciation. There was one point in connection with that cost which was rather interesting to me and that was that the depreciation and wear on the batteries amounted to more than the cost of power in recharging the batteries. The total cost of a unit of this size per

day was $4.87, and of that cost 41 cents was chargeable to charging batteries and 54 cents was due to depreciation and repairs on storage batteries, and 31 cents was due to depreciation of tires. I had no idea that the depreciation of rubber tires and batteries was so excessive in this connection. The cost of traveling with the horse system he found to be about $4.70 per day in comparison with $4.87 per day for the electric automobile. The mileage comes in here, however, and while the horse was found to average about 15 miles per day, the electric automobile with one charge has a limit of power which would give double that radius, so that it was very much cheaper with the electric vehicle than with the horse. That point regarding the possible field for the automobile struck me as most interesting.

THE PRESIDENT—We have with us to-night a member who has had considerable experience with automobiles, who is in fact somewhat of a crank on the subject, and I am sure we would like to hear from Mr. H. P. Davis.

MR. DAVIS—Mr. Scott has given me an introduction that I fear I hardly deserve. My experience with automobiles has been entirely in the pleasure line and I cannot undertake to discuss Mr. Maxim's very able paper. However, any one interested in automobiles is always ready to talk about them. About two years ago I got the automobile craze. I attended two or three shows, secured all the catalogues in existence, and tried to decide what automobile to get. I know a good deal about electricity—or thought I did—so I cut that out right off. This brought the question down to steam or gasoline, as I wanted to do a good deal of touring I bought a gasoline machine. After I purchased it I found however we did not have any country roads good enough to travel over until late in the season. I had the machine a whole year and was not able to get far out of Pittsburg until some time in October. My gasoline machine for this whole year did not cost me one cent for repairs and I never had any cause to get out and get underneath it on the road. I sold it a few days ago and to-day I received a letter from the

gentleman who purchased it. (Laughter) Gentlemen, the contents of this letter is quite different from what you think. The gentleman in question lives in California. He wrote me that the machine had arrived and that he was much pleased with it and has temporarily gone out of business. He got it together and I believe drove it from San Francisco to San Jose. The only criticism he had to make was that there was too many handles to manipulate and he talked of marrying some of them off. I find the best machine for pleasure is the gasoline machine because you can take it out and go any distance without troubling about your supplies. One run which I took with this machine—which by the way was of the De Dion type, a French machine, but made in this country, was one Saturday afternoon late in October when with two passengers, averaging 150 pounds each, I ran from Pittsburg to Mercer a distance of about 70 miles. We started at 1 P. M. and arrived at 8 P. M., stopping an hour in Butler. The run from Butler to Mercer we had to make in the dark with the sand on the road six or eight inches deep. We averaged over 10 miles per hour with the machine and did not have to stop or get out except to light the lamps. Coming back I had one passenger and the machine averaged 12 miles per hour. The roads between here and Butler are nothing to brag about. From my experience I can thoroughly recommend the gasoline machine to any one who is looking for a reliable pleasure vehicle. For ladies' use, however, I would recommend the electric.

THE PRESIDENT—We have with us this evening a newly elected member who has had a great deal to do with one phase of automobile work. Mr. Storer has designed several motors for this service.

MR. STORER—I have been very much interested in the discussion here to-night, but do not know that I can add anything to it. As Mr. Scott has said, I have been interested in automobiles almost entirely from the standpoint of the electric motor, and speaking for the motor I can say without any doubt that the

electric automobile should be the greatest possible success and be far superior to any other kind. The electric motor is certainly more flexible than any other form that can be designed. What we have got to look out for to make the electric automobile take the lead and come up to the place it deserves and ought to have from the standpoint of the motor, both for commercial use and as a pleasure vehicle, is to get the right kind of a storage battery. Personally I shall never be satisfied until we are able to take a can of gasoline, or some other light fuel, and have an apparatus on the automobile which will simply turn that into electricity which can be used for driving the motor. Now why cannot some good chemist get down to business and give us this. I do not think that there is anything else that would be worth more money than such an apparatus whether it is chemical or mechanical provided it is light, cheap and reliable. It does seem an outrage that we have to depend upon so sensitive an apparatus as a storage battery to carry us around—one that will simply store up power enough to run a machine 40 or 50 miles. I think the fact that the electric automobile is a success at all is marvelous, considering that handicap, but as Mr. Maxim has pointed out it certainly is the machine which will take the lead, even with that draw-back, in probably 75 or 85 % of business service. And from the pleasure standpoint I would still choose the electric. Not being sporty, I am entirely willing to turn on the juice and let the machine do the running.

The President—Mr. Storer has suggested something in the line of batteries. We happen to have a young man with us this evening who is engaged along this line and he may be able to tell us something of interest in this connection. Mr. Flanders what have you to say?

Mr. Flanders:—It looks as if the storage battery had received quite a black eye this evening. I think one of the reasons why the storage battery is apparently the cause of so much trouble is that it is a new adaptation to the automobile and as applied to automobile service has an exceedingly hard task

set before it. It receives tremendous overloads, due to inexperienced handling, lack of training, lack of interest, which, of course, does it great injury. It is also much abused in the matter of charging and that is really the most frequent trouble in many places. As an example of the severe abuse to which the storage battery is often subjected, it is quite a frequent thing for people to take a storage battery out and completely exhaust its capacity. If a person had a good horse he would not think of applying the lash after the horse had travelled to its limit and the storage battery is in the same situation as the horse. Until it is better understood there will continue to be trouble with it.

Then another reason is the lack of proper design to meet the various requirements of automobile work. When this difficulty is overcome then will come the salvation of the storage battery, that is, when a battery is designed to cover given conditions and when people learn not to exceed the limitations set. Some people expect electric automobiles to do all sorts of impossible things because it can for a few times, give a mileage in excess of its rating, but not without injury. The gasoline machine will lie down absolutely if you attempt to overtax its power. The storage battery, as I have said, will do its work, but care must be exercised not to injure it or you will have trouble the next time you take out your machine. What we want is a good battery that will give us a reasonable mileage, and that will be fool proof. Judging from the progress made in the past and the number of patents that are being taken out in connection with storage batteries, this point of designing batteries for specific conditions of operation is receiving much attention and we have great promise that in the near future we will have a storage battery that will be reasonably successful. Beyond a certain limited mileage, however, it is impossible to expect anything of the electric automobile.

Mr. Lewis:—I can only say that I regret very much that my friend, Shallenberger, is not here as the principal part of

this disscussion on transportation would be very interesting to him. I believe he is the man who described the boulevards as being adapted to the uses of those who desire individual locomotion in congenial companionship. That was in 67 road report.

THE PRESIDENT:—Those old members are always ready on the road question.

MR. HIRSCH:—I think I have seen in a paper somewhere a description of a system of locomotion by which trolley wires are suspended the same as in street railway work. The vehicle, however, does not run on rails but is simply operated from the trolley wires above. Probably Mr. Maxim has seen such a system or knows something about it.

MR. MAXIM:—Such a system is in use in some places in Europe but the installations are not many. I would consider such a vehicle more nearly a street-car than an automobile. They are limited to the trolley wires—the same thing as a track, so that I do not look upon it as an automobile vehicle.

One thing I would like to speak about and that is the "black eye" which the storage battery has received. As I look at it I do not think the storage battery hardly deserves that black eye. I think the trouble with the batteries has been due to the ignorance of the users. We have storage batteries available to-day which are as sound and reliable a piece of apparatus as any electrical machine, but you can injure them just as you can injure any piece of electrical equipment. It, however, does not show its injury at once. One of the recent developments is a device to provide against ignorance in the use with storage batteries. It is the automatic charging outfit which limits the charge. It is not much use to attempt to make storage batteries stronger and better until we can provide for their proper care. I think if the storage battery progresses no further than it is to-day we will have a very good piece of apparatus. The automatic charging outfit on the market to-day is one of the means which will enable ignorant

people to take up the electric storage battery and use it safely.

PROF. KINTNER:—I move you that we extend a vote of thanks to Mr. Maxim. Motion carried.

Adjourned.

CHAS. W. RIDINGER,
Secretary.

CHEMICAL SECTION.

PITTSBURGH, PA., March 20, 1902.

The regular monthly meeting of the Chemical Section was held in the rooms of the Society, the Chairman, Dr. K. F. Stahl, presiding.

The minutes of last meeting were read and approved.

Mr. McKenna reported for the programme committee, papers promised for subsequent meetings.

The committee on Chemical Literature promised extracts for the next meeting. Mr. Camp outlined briefly the work before the Reception Committee in preparing for the meeting of the A. S. A. S. & Ch. S. Suggestions were made by different members of the section as to ways in which the Chemical Section could assist in entertaining the visiting members of the American Chemical Society.

Professor Phillips reported a communication from Prof. Noyes, Editor of the Journal of the American Chemical Society, suggesting that there be prepared by some member of the Section to be read at the meeting of the A. S. A. S. & Ch. S., a paper on a subject involved in the Chemistry or Metallurgy of Iron or Steel. No action taken.

The paper of the evening, by Mr. C. E. Manley, followed. Subject, "The Effect of Annealing Shot or Chilled Iron in the Determination of Phosphorous, by the Permanganate-alkali method." The subject was briefly discussed by Messrs. Walters, McKenna, Camp, Mohr, Leoffler and Kemmery.

The Chairman requested that, in view of the assertion of Mr. Manley, that nitric acid is still retained by the yellow precipitate of ammonio phosphomolybdate after drying at a temperature of 100° cent., the subject be thoroughly investigated by the Section, and named Messrs. Kemmery, Leoffler and Marshall as a Special Committee to report thereon at the next meeting.

On motion the Section adjourned at 10 p. m.

CHAS. H. RICH,
Secretary C. S.

THE EFFECT OF ANNEALING SHOT OR CHILLED IRON IN THE DETERMINATION OF PHOSPHORUS BY THE PERMANGANATE ALKALI METHOD.

BY CHAS. E. MANBY.

It is somewhat interesting to reflect that ten years have already passed since the writer introduced the "Alkali Method in the Determination of Phorphorus," and although a few modifications have presented themselves, yet the essential part remains; *i. e.*, titration of the yellow-precipitate with alkali and using for an indicator or end point phenol-phtalein, which produces a red or phenicine, which produces a blue color in excess of alkali.

In the Proceedings of this Society, Vol. 9, Part 6, is an article by Mr. McKenna, entitled, "Some Sources of Error in Phosphorus Determinations," proving, with the most exact figures, that oxidation with permanganate gives lower results on "shot" samples than by evaporation and baking, but no remedy for this evil, at that time, was sought for; it was generally accepted as inevitable, and so it rested to the present day; and now we have hopes that we can, by mere annealing, obtain the desired result. When a chilled sample of pig metal is dissolved in nitric acid there remains an insoluble residue holding phosphorus which is unacted upon by the oxidizing agents at the boiling point, but by going to dryness and baking to destroy all nitrates, ultimately taking up with hydrochloric acid we obtain all the phosphoric acid in a state favorable to the precipitation with the Molybdic mixture.

Annealing, therefore, changes the conditions of solubility, and is practiced as follows: Place two grammes of the sample in a platinum crucible over a Bunsen flame and bring to a bright red heat for two minutes, occasionally stirring with a

rod; it is well to continue the flame by raising the Bunsen to the lid of the crucible and at the same time point the flame downwards against the lid, which, at this moment is removed, and the gas flame will burn on the surface of the crucible and thus exclude all air from entering or causing unnecessary oxidation of the annealed sample at the moment it is cooling off.

The following is the method in detail of analysis:

Transfer the annealed sample to an Erlenmeyer Flask—capacity 500 c.c., add 40 c.c. hot water, then 15 c.c. strong nitric acid and when the violent action has ceased add 10 c.c. strong hydrochloric acid and allow to simmer gently on the hot plate for five minutes, then add 10 c.c. of a saturated solution of permanganate of potash, this will produce a brown precipitate of manganese-oxide which gradually re-dissolves in the hydrochloric acid already added, if the temperature is maintained near the boiling point. If not cleaned up within ten minutes add a few more drops of hydrychloric acid and sodium nitrite solution (50 grammes per litre). Remove from the plate, dilute slightly and filter off graphite.

To filtrate add 20 c.c. strong ammonia and shake; now add 18 c.c. strong nitric acid and place on the hot plate to clear up at the boiling point; if not clear, add a few drops of sodium nitrite solution, remove from the plate and cool off between 90° and 95° C. The amount of solution at this stage should be about 100 c.c., for if too concentrated, then the precipitate separates too quickly and gives a fine precipitate troublesome to filter.

This point of proper dilution is important in promoting a granular precipitate which settles quickly and filters rapidly.

A small line on one of the flasks at a 100 c.c. mark will be a sufficient guide to level up by when running many determinations together. As previously stated 90° to 95° C. is the best temperature at which to add the 70 c.c. molybdic acid mixture. It is not necessary to use the thermometer each time, because two flasks at a time can be removed from the plate

during the boil and by shaking off the live steam and then adding the 70 c. c. molybdic mixture the results are perfectly uniform and give results which do not vary .001 per cent. phorphorus. After the molybdic-mixture has been added, shake a few times at intervals. The filtering can be started in ten minutes from the time of adding the precipitant, wash twice with 1 per cent. nitric acid-wash-water, then with a 2 per cent. solution of sodium nitrate until free from acid, using for an indicator a solution of three drops standard alkali for litre of water and three drops phenolphtalein. Use a small porcelain crucible filled with this colored indicator and allow a few drops of the filtrate to fall into it, which will maintain its pink color if sufficiently washed but bleaches immediately as long as any free acid remains on the filter.

In practice about 70 c.c. of wash-water should suffice. Remove the filter and place in an eight ounce Erlenmeyer flask provided with a rubber stopper, now pour in about 30 c.c. water previously sensitized with alkali and phenolphtalein, insert the rubber stopper and shake until the filter proper breaks up. At this stage the solution is a canary yellow; then run in from a burette the standard alkali until the yellow color changes to red, again shake and add a few drops of a saturated solution of phenolphtalein in alcohol, and which is also previously sensitized with sufficient alkali to produce a ruby red. The phosphorus solution will now assume a deep carmine due to excess of alkali, titrate back with standard nitric acid until the pink is bleached; lastly add alkali to the point where one single drop restores the solution to a light shade of pink. If prefered, the excess of alkali may be added previous to the 30 c.c. sensitized water, but always be cautious to have an excess of alkali before adding the strong solution of phenolphtalein else it will produce an off color of a greenish tint due to part reduction of molybdic acid. Now, take the readings of the two burettes and the difference gives the percentage of phosphorus when divided by 100. The following

results are given as a comparison with the different methods:

By "gravimetric" is meant the regular method, i. e., the sample is dissolved in nitric acid (1.20) evaporated in dish to dryness and baked, taken up with strong hydrochloric acid, the excess of acid evaporated off then 5 C.C. strong nitric to decompose any excess of hydrochloric acid—then dilute and filter off silica—the filtrate is then made alkaline with 20 C.C. ammonia then acidified with 18 C.C. strong nitric—then heated up to 90° C. to 95 C.C. and Molybdic acid mixture added to precipitate the phosphorus. Filter on a tared filter with 2% nitric acid—wash till free from iron—dry between blotters and place in an oven to dry for 1 hour at 125° C.

"Baked and Titrated" means the sample was treated in the same way as "gravimetric" as far as going to dryness and baking and preciptating—not filtered on a tared filter, but finally washed with nitrate of soda-wash and then titrated.

Chilled Iron Phos. .094	Same Annealed Phos.		Gravimetric Phos.
Sample 1	.108		.108 and .106
2	.083		.083
3	.099		.100
4	.090		.091
5	.095		.092
6	.102		.105
7	.093		.095
8	.090		.090
9	.086		.088
10	.093		.095
11	.085		.090
12	.092		.094
13	.078		.080
14	(.320		.329
15	(.302	Baked & Titrated	.304
16	(.292	" "	.295
17	(.250	" "	.252
18	(.280	" "	.280
19	.280	" "	280

In the course of these experiments the writer finds there are indications with samples of high phosphorus iron with two tenths per cent. and upwards of variations when weighing the yellow precipitate after drying at 100° C. and these results are higher than those by titration. See No. 14 sample. This, the writer attributes to the presence of nitric acid held in the precipitate when washed with 2% nitric acid and which is not removed by drying at 100° C.

If nitrate of soda wash water is used for a final wash the titration shows that no nitric acid remains. In making up the molybdic solution it is the writer's practice to purify the ammonical solution with a few drops of bromine and filter off the impurities after which it is poured slowly into hot 1.20 nitric acid. The solution assumes a yellow tint when cold, due to the excess of bromine, and it has the advantage of preventing free molybdic acid separating out at a temperature of 90°–95° C.

JOHN A. BRASHEAR,

SEVENTH PRESIDENT OF THE SOCIETY, 1889.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and twenty-fourth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, April 15, 1902, at 8:15 P. M., with the President, Mr. Charles F. Scott, in the chair, and ninety-two members and visitors present.

The minutes of the preceeding meeting were read and approved.

The Board of Direction reported that the new Membership List is in the hands of the printer, and that any member wishing to make any further changes in his address or business connection should send same in at once. The Board also wishes to report that they have rented the Assembly room to the Foundrymen's Association, for the first Monday in each month.

The Constitution which had been prepared by a former committee, has been recast, by the Board of Direction, into By-Laws conforming to the Charter. These By-Laws are now presented to the Society by the Board, who recommend that they be brought before the Society for adoption at the May meeting.

The Board of Direction then reported the names of thirty-four applicants for membership that had been approved, and would be voted for at the next regular meeting.

THE PRESIDENT—In the report of the Board of Direction there is one point which ought to come before the Society for action. The Board presented to the Society the new By-Laws and asked that these come up before the Society at the May

meeting, and that notice be given that the By-Laws will come up for adoption at that meeting. Announcement to that effect will be made to the members in the May Announcements. There are a few copies of the By-Laws which will be in the hands of the Secretary, and may be consulted by any one desiring to do so.

The following persons were then balloted for and duly elected to membership.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
HOWARD L. BODWELL,	Engineer, Engineering Department, American Sheet Steel Co., Vandergrift Building, Pittsburg, Pa.	S. B. Ely, H. H. Anderson.
SAMUEL G. BRIGEL,	Assistant Engineer, Westinghouse Electric & Manufacturing Co., Pittsburg, Pa.	Chas. F. Scott, Thos. H. Perkins.
CHAS. H. CLARK,	Structural Draughtsman, Jones & Laughlin's, Pittsburg, Pa. h. 3317 Bouquet Street., Pittsburg, Pa.	Chas. F. Scott, R. B. Kernohan.
WILLIAM A. DICK,	Designing Electrical Engineer, Westinghouse Electric & Manufacturing Co., Pittsburg, Pa.	Chas. F. Scott, Thos. H. Perkins.
PEARL N. JONES,	Engineer, Westinghouse Electric & Manufacturing Co., Room 207 Westinghouse Building, Pittsburg, Pa.	Chas. F. Scott, P. H. Thomas.
EMANUEL KAUFMAN,	President and General Manager, Westmoreland Steel Co., Pittsburg, Pa. h. 5422 Howe Street, Pittsburg, Pa.	J. W. Landis, N. C. Wilson.
WILLIAM M. KENNEDY,	President, Pittsburg & Western Railroad, Pittsburg, Pa. h 246 Broad Street, Sewickley, Pa.	E. B. Taylor, Thos. Rodd.
RICHARD KHUEN, JR.,	Division Engineer, Pittsburg Division, American Bridge Co., Pittsburg, Pa. h. 5518 Ellsworth Avenue, Pittsburg, Pa.	J. K. Lyons, E. Swensson.
HERMAN LAUB,	Civil Engineer, Lewis Block, Pittsburg, Pa.	K. F. Stahl, P. A. Lange.
HIRAM P. MAXIM,	Engineer, Vehicle Motor Dep't, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. h. 6201 Howe Street, Pittsburg, Pa.	Chas. F. Scott, H. P. Davis.

RUEBEN MILLER, Jr.	General Superintendent,		Chas. F. Scott, C. B. Albree.
Crucible Steel Company of America, h. 4917 Wallingford Street, Pittsburg, Pa.			
R. A. McKINNEY,	Purchasing Agent,		R. B. Ely, H. H. Anderson.
American Sheet Steel Co., Room 98 Vandergrift Building, Pittsburg, Pa.			
EDWIN M. OLIN,	Electrical Engineer,		Thos. S. Perkins, Chas. F. Scott.
Dynamo Testing Dep't, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. h. 1112 Centre Street, Wilkinsburg, Pa.			
JOSEPH M. SEARLE,	Manager,		D. Hunter, Jr. C. W. Ridinger.
General Engineering & Construction Co., Pittsburg, Pa. h. 326 Fourth Avenue, Pittsburg, Pa.			
WM. MacG. SHIRAS,	Manager,		A. N. Deihl, J. M. Camp.
United States Steel Corporation, Pittsburg, Pa. h. 715 College Avenue, E. E., Pittsburg, Pa.			
FRANK H. TAYLOR,	Second Vice-President,		Chas. F. Scott. P. A. Lange.
Westinghouse Electric & Manufacturing Co., Pittsburg, Pa. h. 7422 Penn Avenue, Pittsburg, Pa.			
WILLIAM T. WALLACE,	Principal Assistant Engineer,		Geo. S. Davison, E. Swensson.
512 Smithfield Street, Pittsburg, Pa.			
HENRY H. WESTINGHOUSE,	Vice-President,		Chas. F. Scott. E. M. Herr.
Westinghouse Air Brake Co., Pittsburg, Pa.			

The President—Mr. Albree has an announcement which he will now make.

Mr. Albree—The papers this evening, as you know, deal with the application of the electric motor to modern work, and among them is one by Mr. Wales, touching such applications out in the Homestead Steel Works. Thinking that an excursion to these works would be of very great interest to all the members, the Reception Committee got permission from the authorities of the Carnegie Steel Company for the members to go through the Homestead Steel works, Tuesday evening, April 22nd. Arrangements will be made to have special electric cars to run to Homestead, and a notice of the arrangements will be mailed to all members within a few days.

The President—The subject this evening is the "Electric Motor in Industrial Establishments"; a subject which at the time this Society was founded twenty-two years ago,

would have been a topic on which little or nothing could have been said. But it is a subject which has come to very great prominence in modern industrial establishments where power is used and distributed, and the use of power is really the great vital element in the work which is to be done. We know in a general way the steam engine is the basis of our modern work, but the more closely one will study into the methods of manufacture the more will he be impressed with the fact that our modern plants are simply means by which mechanical power is used and directed by men. Men are no longer the workers, they are the directors of power which is produced in larger quantities than is possible to develop with mere human muscle. And as manufacturing develops it is the method of applying the power which is one of the most important elements and is worthy of the most careful study and consideration. The method of applying power developed in large units to meet the varied requirements of separate and individual machines, some requiring constant power and constant speed; others intermittant power, and others varied speed, is a very difficult problem. But there is no method of general distribution of power which is comparable in flexibility, efficiency, and general effectiveness with electrical distribution. The fact that the electric motor and electric power distribution have become prominent and so indispensable in the growth of the last decade lies in this fact. The steam engine and the water wheel are old, and machinery is old. Electricity comes in as a link between the source of power and the machine, and, being a flexible and efficient link, fills a long felt want. The motor has come into the field quickly because conditions were ready for it; and it has come to be a very important factor in our modern work. The classes of motors in commercial work are but few. The kinds of motors possible and the different sorts of electric systems possible are almost legion, but practice has brought about a few simple standards. One is the direct current motor for mill work, al-

most universally used at 220 to 250 volts. Sometimes 500 volts is used but for mill work and ordinary industrial plants 250 volts is the standard. Again, there is the alternating current induction motor—either two or three phase—which is simpler in construction and which has different electrical characterics as to its speed, torque, etc. This form of motor has become very widely used. Both of these motors have their own characteristics, fitting them the better for particular kinds of work, and both are employed to a large extent. In general, each can do work which the other can do, and there are contentions here and there as to which is most suited for particular cases, but whatever may be the advantages which each possess, both are doing good and satisfactory work. The plants to be described this evening employ both classes of motors. The first paper is by Mr. S. S. Wales. Mr. Wales has had considerable experience with this kind of work. He was with the Ohio Steel Company at Youngstown for a number of years, and I remember that Mr. Wales told me, while still at Youngstown four or five years ago, that although they did not have as many motors as were used elsewhere, yet there was not another steel works which depended so much on its motor drives as that of the Ohio Steel Company. He is now connected with the electrical department of the Homestead Steel Works.

Mr. Wales—Regarding the National Steel Company—as it is now—at Youngstown, Ohio, we had there motors from beginning to end. The stopping of any one motor would shut down the converting mill. The stopping of a motor was like dropping a link out of a chain. And yet, depending on motors as much as we did, and motors not being developed as they are to-day, that is, not as reliable as they are to-day, we were able to run up to probably 14,000 tons per day in a mill built for a thousand tons. In working up this paper I have, of course, assumed that every one here is more familiar with Westinghouse apparatus, although I will say, with Mr. Scott's permission, that there are other good motors.

THE ELECTRIC MOTOR IN MILL WORK.

MR. S. S. WALES.

It is not quite ten years since the first systematic attempt was made to utilize the electric motor in rolling mill work, yet it has almost entirely superseded the small hoisting engine in many places, and has rendered some classes of work possible which if accomplished by steam would require an out-fit so cumbersome as to be almost prohititory. One of the most notable applications of electric motors, and one which has been revolutionary in mill work is the over-head traveling crane which is used over stock track for handling raw material, pouring steel, for handling ingots to and from the heating pits and for sorting and loading cars for shipment. To do without this crane would be a hardship, and to replace the motor by steam engine, rope drive or square shaft would be almost out of the question.

The next in importance and in reality a brother of the crane is the horizontal charging machine which is used in charging open-hearth furnaces, and in handling large slabs and blooms to and from the horizontal heating furnaces.

Another large field of application is on the roller-table, which is such a typical piece of machinery in mill work. Here the adaptability of the motor depends not so much on its lightness as on the absence of long steam pipes which act as condensers, and the complication of reversing levers. The screws on bloom, slab and plate mills are now largely driven by motors, and in up-to-date boiler plants, using mechanical stokers, the coal is carried to storage by motor-driven conveyors, from these delivered to boilers by motor-driven coal-handling machines and finally the ashes are loaded into cars by mall motor-driven skip-hoists.

So it will be seen that at this time electric power has edged its way into all branches of the steel business. As an example let us look at the latest steel-producing and roll plants of the Carnegie Steel Company. The steel scrap, in broad gauge cars, is placed within reach of five-ton electric stock cranes which handle the material into charging boxes and place them on narrow gauge cars. These are taken to the furnaces and the material charged by electric charging machines and required amount of iron is charged, in the molten form, by over-head ladle cranes. The finished steel is carried by large over-head ladle cranes to the pouring platforms where it is tapped into the ingot molds. After being stripped the ingots will go, let us say, to the slabbing mill where they will be charged in the heating-pits by vertical electric charging cranes, and are carried by them to the rolls when heated. The ingots now pass through the rolls which are adjusted by electric-driven screws, and from there through the shears, the slabs being handled by electric crane. They now go to the plate mill where they are charged and drawn by horizontal electric charging machines and delivered by electric-driven roller-tables to the mill rolls which are adjusted by motor-driven screws. From the rolls the plate is carried by motor-driven tables to the cooling and straightening beds, and after being sheared to size is loaded for shipment by over-head electric cranes. All this sounds very smooth and quiet, but it is in reality attended with—a certain amount of trouble and delay caused by rough usage of machinery, too small motors, chronic neglect to oil, or a roller bearing so tight as to form a brake and occasionally a key-way in the line shaft babbited into a bearing during Sunday repairs.

All the things a motor will do, or can be subjected to without material damage, and why, is for the future to decide. I have seen motors do good work surrounded by the most ideal conditions, and have also seen them give endless trouble in apparently the same conditions. I have seen motors work under conditions which were diametrically opposed to the

theory of their construction and operation. I have to-day two fifty horse power, four five horse power and two three and a half horse power series motors, direct connected to screw, which are brought to a stop by being driven against an ingots and although they have no other protection than a controller, which is operated by hand, they give little trouble and are seldom if ever burnt out.

The Electric Motor is the most conscientious machine ever designed. This trait alone has laid it open to much abuse, with the result that many of the effects of over-work have been charged against it as constitutional defects.

A motor is constructed with the intention that the armature shall turn, and if properly connected, turn it will or wreck itself in the attempt. Granting that it can turn with the load it is given to carry it will continue to do the best it can until almost burned up. The fact that a motor will run even with an injurious over-load, coupled with a general misconception of the meaning of the manufacturer's rating has resulted in the general application of motors much too small for their work, and this, too, by engineers who would never think of falling into the same error with the steam engine. Further, firms which build motor-driven machinery, on account of close competition, almost uniformly under-estimate the size of motor required for the work, although their calculations of actual power required may be perfectly correct. The motor specified will certainly do the work at the acceptance test of the machine but may break down in less than two weeks of factory operation, by which time the machine is probably paid for and it lies entirely with the purchaser to keep up the constant repairs required, or to make such changes as are necessary to adapt the next larger size motor to the machine. Wherever this state of affairs exists the latter course should be followed if possible, as the constant replacing of burnt-out armatures and fields soon eats up the cost of the larger machine, in addition to loss in time and unreliable service.

The surest way to avoid this difficulty in most cases is for the the electrical engineer in charge of the work to specify the type and minimum capacity of each motor that he will accept, thus freeing this vital part of the machine from the competitive reduction in size to which it would otherwise be subjected.

Motors for mill use may be of any or every type built, but in any case it is probable that no single type would cover the ground satisfactorily under all conditions. All have their able advocates whose reasoning is very convincing to others, and perfectly satisfactory to themselves. At the present time no motor has had such diversified application in this line as the Standard Street Railway Series Motor; its claim for recognition being the powerful starting effort, its complete mechanical protection from external damage, and the fact that it is a standard article turned out in large numbers from the electric companies and therefore can be obtained on short notice. Its drawbacks are its high speed at very light loads and its lack of ventilation. The writer is inclined to favor this type for a large proportion of mill work, though not averse to the open-type series, shunt or compound-wound motor, for driving certain classes of machinery for which they are especially well fitted. The open type has the advantage of easy access for inspection or cleaning, but it offers no protection from foreign substances, small pieces of iron, crowbars, etc., which are very likely to come within its field of attraction during ordinary mill operation.

In the earlier days of electric power development a great deal of reluctance was shown by the manufacturers of electrical apparatus in regard to giving detail of performance of their motors to the prospective user. This led to series motors being applied to work at their nominal rating as to output and speed, which would uniformly result in over-load, or if the attempt was made to reduce the load by increasing the size of motors, the speed of operation would be much higher than the

figures showed. At the present time there is no difficulty in obtaining complete characteristics of any standard motor on the market, so that sizes can be specified and results predicted with a fair degree of certainty.

I will endeavor to show some easy methods of determining the proper size of motor for such work as is ordinarily met with in mill use, such as cranes and tables, not claiming absolute accuracy, but feeling that by following along these lines the user will be on the safe side, although he will often be told he has figured too high.

As in a general crane specification the actual weights of material and gear reduction, etc., are not known, some arbitrary assumptions will have to be made and some empirical formula will be used, but as both are founded on facts and experience some reliance may be placed in them.

An electric crane is divided into three general parts—bridge, trolley and hoist, each of which has its own motor and controlling system, and each subjected to different conditions of work.

For the bridge where the ratio of axle bearings to diameter of wheel is between one to five and one to six, the following table will answer our purpose for weights and traction for different spans.

Let L=working load of crane in tons.
W=weight of bridge alone in tons.
w=weight of trolley alone in tons.
S=speed in feet per minute.
P=pounds per ton required.

Span	W—	P.
25 ft.	.3L	30 lbs.
50 ft.	.6L	35 lbs.
75 ft.	1. L	40 lbs.
100 ft.	1.5L	45 lbs.

For the trolley we would assume the weight and traction as shown in the following table:

L.	W.	P.
1 to 25 tons.	.3L	30 lbs.
25 " 75 "	.4L	35 lbs.
75 " 150 "	.5L	40 lbs.

Now the power required for bridge will be $\frac{(L + W + w) \times P \times S}{33,000} = H. P.$ which result will be used in connection with the motor characteristic to determine the gear reduction from motor to track wheel. As the nominal H. P. rating of a series motor is based on an hour's run with a rise of 75° C. above the surrounding air and as conditions of bad track, bad bearings or poor alignment of track wheels may be met with—in factory operation 1½ times the above result should be taken as the proper size motor for the bridge.

For the trolley the power required would be—

$\frac{(L + w) \times P \times S}{33,000} = H. P.$ which will be used for speed and gear reductions, but 1¼ times this should be used for size of motor.

For hoist work we cannot have so large margin of power, as the variation from full load to no load may imply a possible dangerous increase of speed, and unless the crane is to be subjected to its maximum load continuously or is to be worked where the temperature of the surrounding air will be high, it is safe to use the size by assuming 1 H. P. per 10 ft. ton per minute of hoisting. This is nearly equal to assuming the useful work done as 60 per cent. of the power consumed.

As an illustration, let us take a crane of 50-ton capacity, lifting speed of hoist fifteen ft. per min. Bridge to be 70 ft. span and to run 200 ft. per min. with load. Trolley to travel 100 ft. per min. with full load. On the foregoing assumption the bridge would weigh 50 tons and require 40 lbs. per ton for traction, and the trolley would weigh 20 tons, and require 35 lbs. per ton for traction.

The power for the bridge would be
$\frac{120 \times 40 \times 200}{33,000}$=29 H. P. and the size motor 1½
times this would give 43½ H. P. or 50 H. P. this being the nearest standard size, and the specification should read not less than 50 H. P. motor to be used for bridge travel. (See Fig. No. 1.)

Assuming Westinghouse motors to be used, as they are more commonly known in this district, this would call for a No. 38—50 H. P. railway motor. By referring to characteristic sheet for this type (see Fig No. 2,) we find that at 29 H. P. this armature will run 612 R. P. M., which, when the dia. of the track wheel is known, will give the gear reduction needed.

Similarly the trolley will require $\frac{70 \times 35 \times 100}{33,000}$=7.43 H.P. and the size motor required will 1¼ times this, or 8.28 H. P. or 10 H. P. Dust-proof as the next standard size and the specification would read not less than a 10 H. P. motor to be used. The characteristic of a Westinghouse 10 H. P. motor shows that the armature will run 820 R. P. M. at 7.43 H. P.
The hoist would require $\frac{50 \times 15}{10} = 75$ H. P. and would be specified not less than 75 H. P. motor to be used on the hoist. The next standard size Westinghouse motor suitable for crane service is the No. 76 rated at 80 H. P. at 220 volts and the armature speed at 75 H. P. is shown on the characteristic (see Fig. No. 3,) to be 460 R. P. M. The required power will of course be modified by the requirements of special cases, the use of rope or chain, whether the reduction is made mostly in the chain or in the gearing, etc., but still they will give reliable results to the user.

The power required by roller tables in mill work varies greatly as they are subjected to the "tight bearings" and lack of oil to a greater extent than electric cranes, and as there will

be from $2\frac{1}{2}$ to 3 bearings to each roller and many rollers per table, these chances for trouble are greatly multiplied.

For the average conditions of mill tables where each roller is driven by a miter gear from a common line shaft and with usual mill lubrication, the following empirical formula derived from the test of twenty tables represent about the power required:

$$\frac{W \times D \times S \times N}{950{,}000} = \text{H. P.}$$

Where W = weight of roller in pounds, the load to be carried on table being considered as uniformly distributed over all rollers, 1-N to each.

D=dia. of bearings in inches.

S=Speed of table in R. P. M. of rollers.

N=Number of rollers in table.

The same $1\frac{1}{2}$ times power required for size of motors should be taken as for crane bridges.

This takes no account of diameter of roller used, which would of course have some effect on the power required to move the load to be handled, and would also show some fly-wheel effect when starting, but still it will check fairly well with tables now in use under existing conditions, two examples of which are given here:

N = 18.

W = 1600 lbs.

D = $4\frac{1}{2}$ inches.

S = 200, R. P. M.

Diameter of roller 10 inches.

$$\frac{1600 \times 4\frac{1}{2} \times 200 \times 18}{950{,}000} = 27.2 \text{ H. P.}$$

From actual test under working conditions this table required 28.8 H. P. or the nearest Westinghouse motor being No. 38—50 H. P., this type should be used. The characteristic of the No. 38 at 27.2 H. P. shows an armature speed of 632 R. P. M., which would show a reduction of about 3.2 to 1 from armature

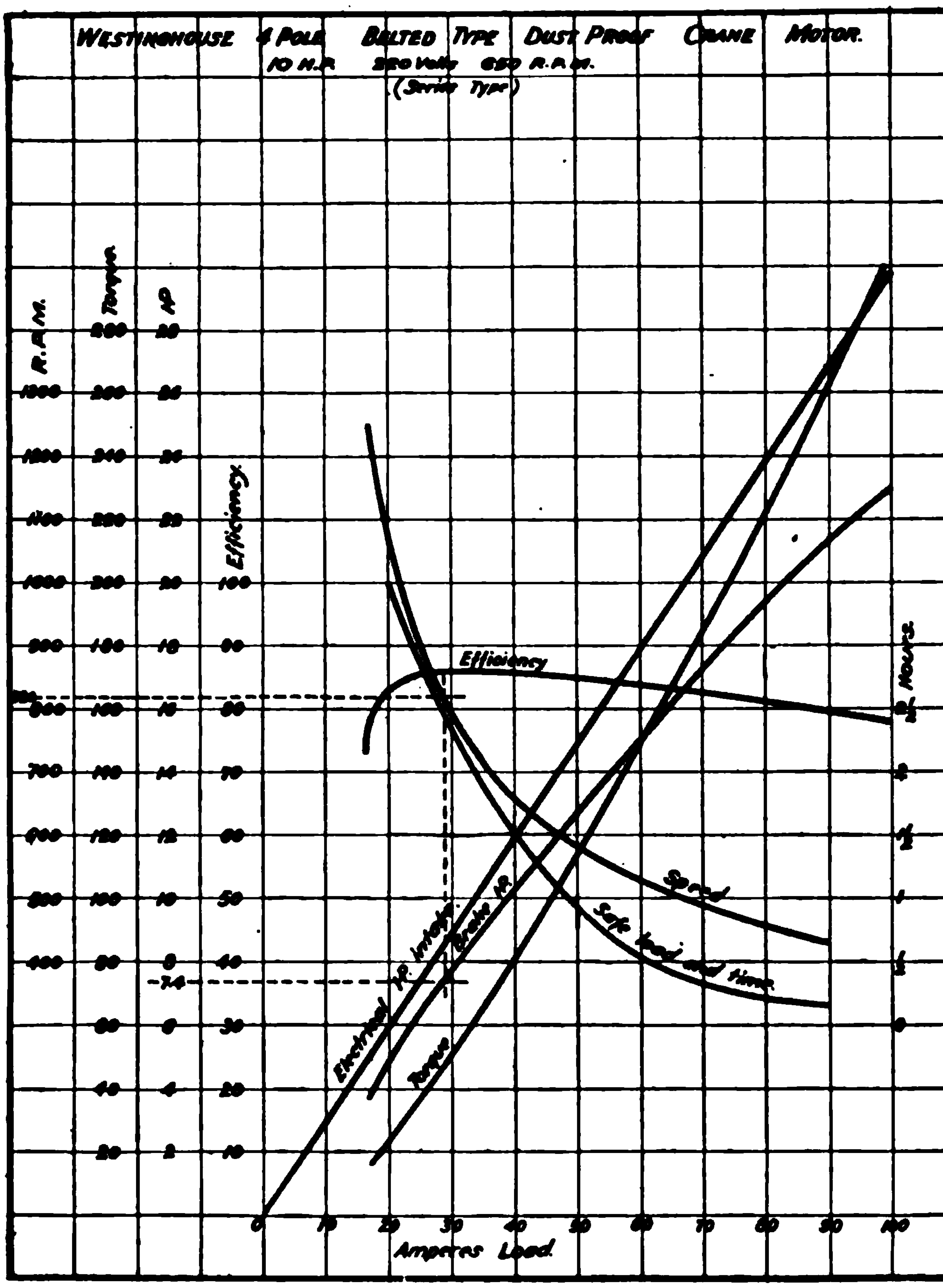
Westinghouse 4 Pole Belted Type Dust Proof Crane Motor.
10 H.P. 220 Volts 650 R.P.M.
(Series Type)
R.P.M.
Torque
HP
Efficiency
Efficiency
Speed
Safe load and time
Electrical H.P. Intake
Brake HP
Torque
Amperes Load
Hours

FIG. No. 1.

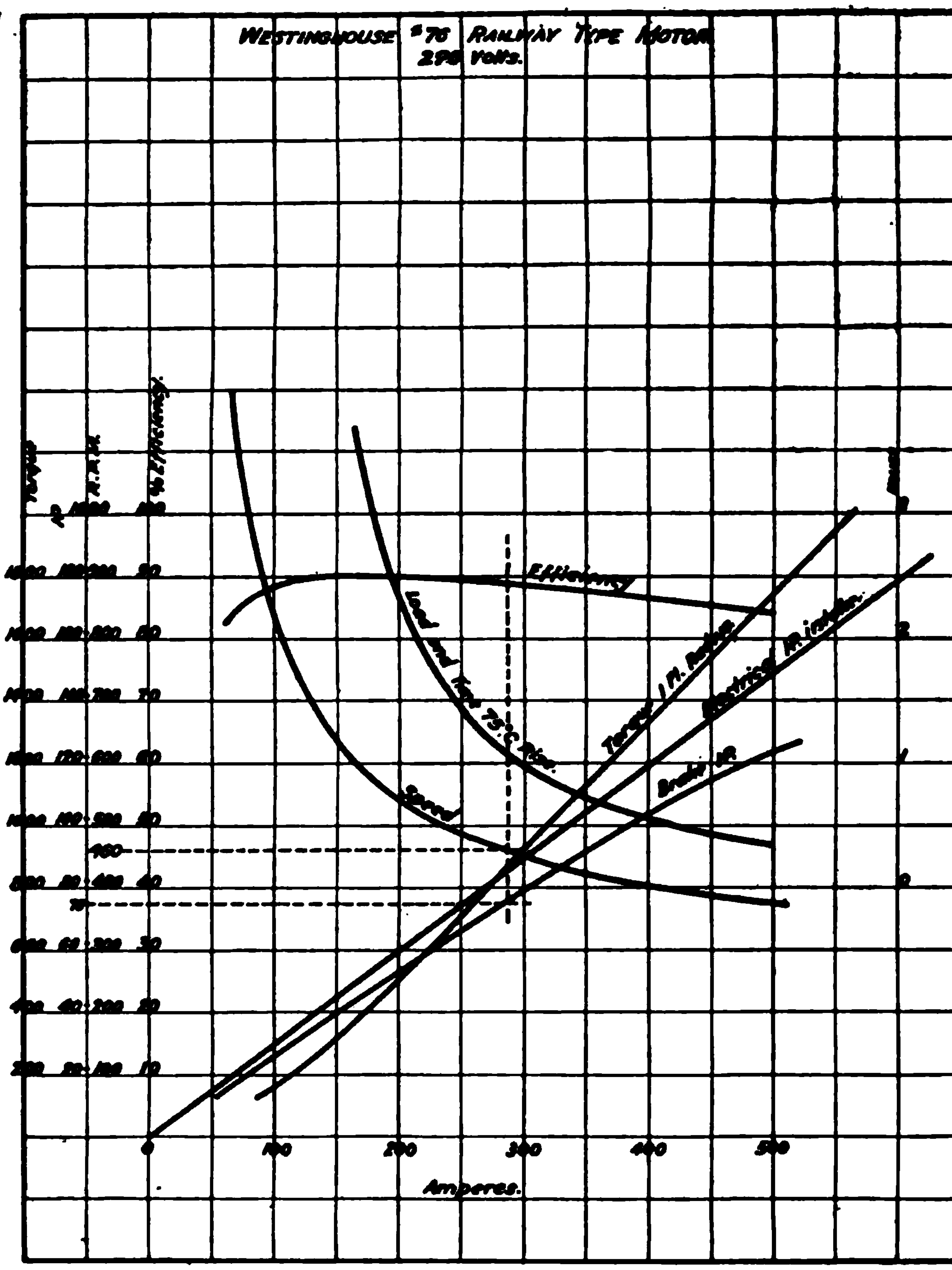
WESTINGHOUSE #76 RAILWAY TYPE MOTOR
Amperes.
Efficiency
Speed
Torque 1 Ft. Radius
Electrical H.P. intake
Brake H.P.
0
100
200
300
400
500

FIG. No. 2.

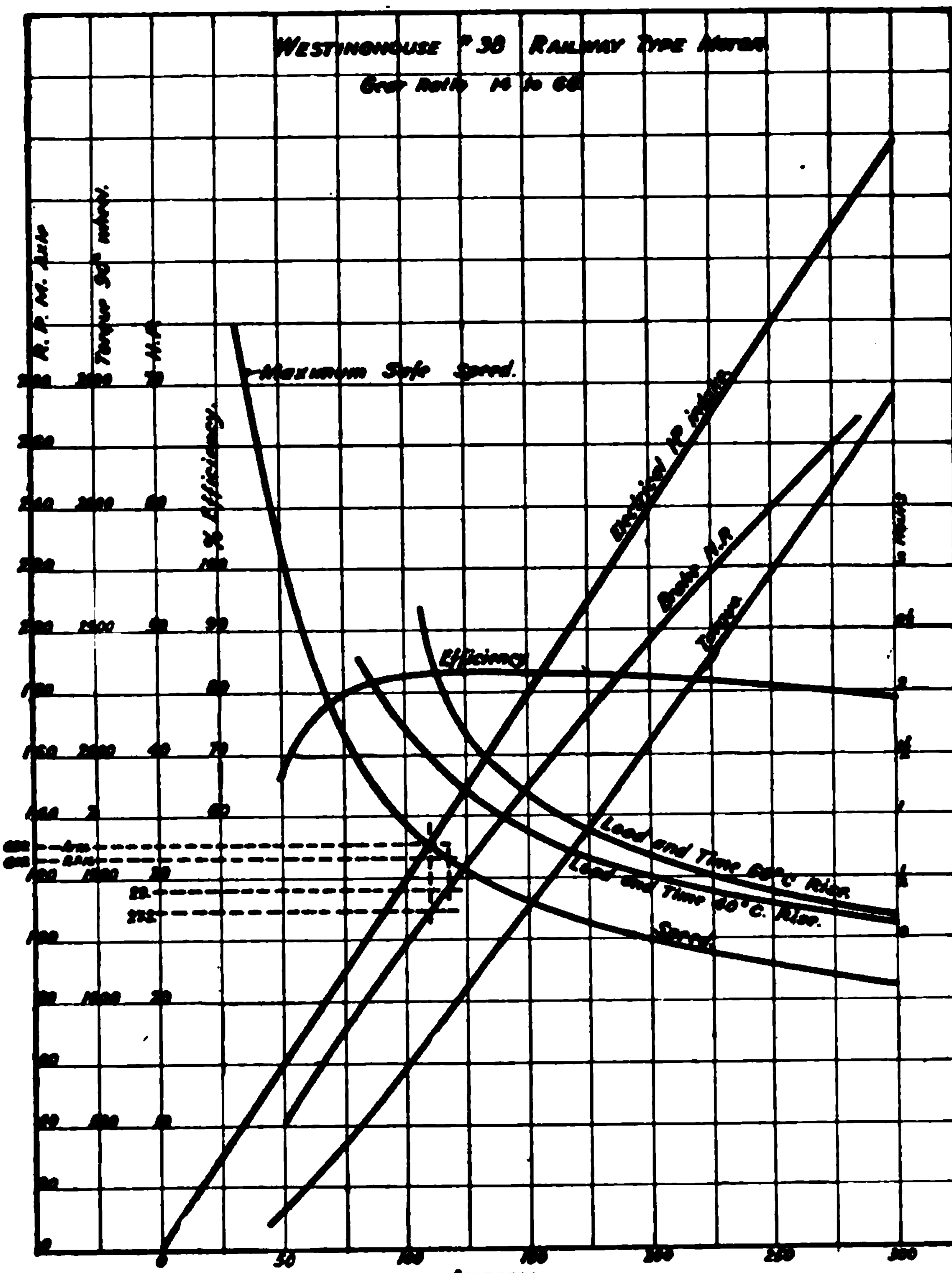

FIG. No. 3.

to roller. As a matter of fact this table is equipped with a 30 H. P. motor and is the source of continual annoyance from over-load.

$$N=16.$$
$$W=1000 \text{ lbs.}$$
$$D=3 \text{ inches.}$$
$$S=110 \text{ R. P. M.}$$
$$\frac{1,000 \times 3 \times 115 \times 16}{950,000}=5.8 \text{ H. P.}$$

By actual test 5.5 H. P. was required.

As mill operators become more familiar with—proper handling of motors, and engineers become more liberal in specifying sizes, the electric motor is destined to fill a still larger field in mill work than is even now thought of.

THE PRESIDENT—Since Mr. Wales has questioned somewhat the ability of the designer of the motor to know what he has designed, we will now ask Mr. Storer to take up the question, since he is responsible for some of the motors Mr. Wales has been discussing.

SOME CHARACTERISTICS OF DIRECT CURRENT MOTORS.

MR. NORMAN WILSON STORER.

The other papers presented at this meeting contain a very complete description of the uses to which electric motors are being put and of the excellent work they are doing in the great steel mills in and around Pittsburg. A large part of the advantage which is derived from the use of electric motors is due to the ease of the transmission of power from the central power station to the place where it is to be used, but a great deal of it is also due to the motor itself and to the ease with which it may be placed and adapted to perform the different operations.

As is inevitable in the development of anything so radically new as the electric motor and especially in its application to mill work, some mistakes have been made which have

been both troublesome and expensive, but such mistakes are now for the most part ancient history, as their causes are pretty well determined. The mistakes have been due chiefly to three causes, viz.:

(1) Insufficient knowledge of the power requirements of the work to be done.

(2) Insufficient knowledge of the characteristics and capacity of the electric motor.

(3) A lack of knowledge as to the type of motor best suited for the work.

Judging from the papers that have been presented, it would seem that the first cause is being eliminated. A systematic effort has been made to determine the actual requirements for the various operations, and calculations are made with a good knowledge of the efficiency of all the different parts of the machinery which is to be operated. This knowledge has resulted from experience and its application with plenty of common sense, which is the backbone of all good engineering. Common sense and judgment are especially necessary in determining the sizes of motors for most of the operations in mill work where the loads fluctuate so frightfully, friction varies between such wide limits, motors are started and stopped with practically no use of the starting resistances, and all the difficulties imaginable that can result from bad handling of the motors are likely to arise. In such service it is not to be wondered at that mistakes have been made, and if the same mistakes are not repeated, the engineer is to be congratulated.

The second cause of trouble is closely allied with the first. It is very difficult for the designer of electric motors to rate them in terms that will correspond to all classes of the service which they are required to perform. As has been stated before, the electric motor is such a conscientious piece of machinery that it will continue to run as long as it is supplied with current, until its temperature becomes so high that

the insulation will be destroyed and the motor burns out. For this very reason, it is likely to be overloaded until the operator learns its limitations. For motors of the enclosed type, for a class of work such as starting and accelerating heavy loads continuously, the limit to the capacity of the motor is found to depend not on the maximum speed to be attained nor the maximum load to be carried at any time, or even the average load to be carried, it depends principally on the average loss in the motor, which, in turn, determines its temperature rise.

In the various cycles of work the motor has to perform, such as starting, accelerating and running for short periods with various loads, certain losses occur which develop heat in the motor that tends to raise its temperature. No one cycle will last long enough to raise the temperature more than a few degrees, but a succession of cycles will after a few hours raise the temperature to a point where the radiation of heat will equal the losses. If this final temperature is above the safe temperature of the motor, the insulation will deteriorate rapidly and it will be only a question of time when the motor will burn out and will have to be re-wound. In such a case, a larger motor should be used or the duty required of it should be decreased. In case the final temperature is below the safe limit and the maximum requirements are below the commutating limits and mechanical strength of the motor, more work may be required of it, or a smaller motor may be substituted.

It is the general practice, however, to use a few standard sizes of motors and to use the smallest of these that will do the work.

The great problem in motor selection is to determine, first, what the loads are going to be, and second, to find what motor will be required to perform the work. It is useless to try to select a motor until the duty required of it is pretty well understood and the relation between this duty and the capacity of the motor is determined. It is very difficult for

the designer to assign a rating for the motor or to describe its capacity without having a working knowledge of the service which is expected of it. It is therefore necessary that the engineers in charge of motors in such service should make up specifications giving a definite statement of the requirements. This has very rarely been done. It is not sufficient to call for a motor rated at 50 H. P. without giving additional characteristics as to the range of loads, the average load desired, and temperature limit. If this is not done, it is unreasonable to object if the motor does not meet the requirements.

Some of the curve sheets given in Mr. Wales' paper contain "Safe Load and Time Curves." These curves show the time the motor will carry the various loads within its capacity with a certain rise in temperature. This method of stating the capacity has been in use for some years and has been of great assistance to the engineers who wish to select motors for certain work. The speed and torque curves show the ordinary limits between which the motor should be worked.

In connection with the question of rating mill motors, it may be interesting to mention the method of rating railway motors which has been adopted by the Westinghouse Electric & Manufacturing Company. Railway motor work is in many respects analogous to mill motor work. The railway motor is called upon to go through a series of cycles more or less regular, of acceleration, running at full speed, coasting, brakeing and standing still, very similar to the work required of mill motors, except that the conditions are such that the work may be analyzed much more definitely. The foundation of the method of rating consists in making a careful analysis of the work which railway motors have to perform with a view of determining the losses which occur in them during ordinary service. The losses, which are chiefly influential in increasing the temperature, are, first, losses in the winding, due to the resistance of the copper to the passage of the current, and second, losses in the iron core, due to reversals and fluctuations

in magnetism. Unfortunately for the engineer who is calculating the average losses, the loss in the windings depends not on the average current, but on the square of the current, so that it is necessary to determine the square root of the mean square current in order to determine the average copper loss. This is not difficult, but requires a great deal more work than simply averaging the load of the motor. The iron loss is a function both of the current and the voltage, but it may easily be determined if the characteristics of the motor are well known and the cycle of operation through which the motor passes is understood. When once these losses are known, it is a very simple matter to determine whether the motor will be able to stand the average loss continuously without overheating. In order to simplify this work, the continuous capacity of 500 volt railway motors has been expressed in terms of the currents which they will carry continuously at 300 and 400 volts. Where the motors are started and stopped as frequently as in ordinary street railway service, the voltage of 300 will be high enough to develop the full average iron loss of the motor. The nearer the motor approaches a service requiring continuous operation under load, the higher the voltage should be for the continuous test, until where the motor operates continuously it should be rated at the voltage of supply.

This method of stating the capacity of railway motors has proved very satisfactory, and while it is not as easy in many cases to predetermine the service requirements of power and time for mill work as it is for railway work, the same method may be applied to mill motors. The most important thing to do is to carefully analyze the work which the motor has to perform, determining as far as possible the limits in speed and torque, and from the average load determine what the average losses in the motor will be. It is very difficult to select a motor of any class of service intelligently without such an analysis.

In some cases, the temperature of the motor is not in any

degree the limit. The motor may be occasionally required to handle enormous over loads which will not be applied long enough to raise the temperature of the motor to an injurious degree. Motors for such service must have a very large margin for commutation as well as for mechanical strength, and it is sometimes necessary to select very much larger motors for the work than the average power requirements would seem to need.

In this connection, it may also be mentioned that the external temperature has a great deal to do with the capacity of the motor. If the air temperature is very high, a larger motor must be selected to do certain work than if it were to perform in a low atmospheric temperature. The work itself will cause a rise in temperature of the motor of a certain number of degrees. It will be readily seen that the air temperature will thus have a very important bearing on the final temperature of the motor.

The third cause of mistakes is probably the least—a lack of knowledge of the type of winding best suited to the work. This concerns almost entirely the speed and torque regulation of the motor. The type most commonly used for mill work is the series motor, which is the one universally used for railway service. The series motor has a capacity for starting enormous over loads, because the heavier the load is, the stronger becomes the field and the greater the torque that can be developed with a given current. Not only is the torque greater for a given current but the commutation is also much assisted by the increased field strength. The speed curve of the series motor takes somewhat the form of the hyperbola. On light load the speed increases and the torque decreases rapidly. If the load is entirely thrown off the motor it will reach a dangerous speed. This motor is thus unsuited for any work except where the speed variations do not interfere with the work and where the minimum load is always sufficient to keep the motor from running away.

The type of motor which is least used for mill work is the

shunt motor; its field for operation is in service requiring a practically constant speed with comparatively small fluctuation in load. The field is constant at all loads and the motor is not adapted to starting or running extremely heavy over loads.

The type of motor intermediate between the shunt and series is the compound wound motor. This motor has both shunt and series windings on its field and partakes of the characteristics of both the shunt and series motors; it has the capacity for handling a load which fluctuates between wide limits and, due to the shunt winding, it can operate at a fairly close approximation to constant speed. The light load may be any desired amount above the full load speed. It is thus very flexible and can be arranged to give any regulation desired, by simply changing the proportions of the shunt and series windings. This motor is especially adapted for operating shears, saws, pumps, and such work. Shunt motors should be used for operating machine tools, mine shafting, etc., where constant speed with comparatively small fluctuation of load is required. The series motor should be used for all classes of service where frequent accelerations of heavy load are required and where the load on the motor is always sufficient to prevent its running away. Its work includes the operation of cranes, roll tables, and all classes of railway work.

THE PRESIDENT—One of the subjects on the program for this evening is a description of the plant of the Westinghouse Air Brake Company. Mr. Vankirk, who was to favor us in this connection, advises that during the past two or three weeks his duties have engaged his attention about 23 hours per day and that, as a consequence, he has not been in very good shape for writing the other hour. However, he will tell us something of the installation at that point from which you will note that the coming of the alternating current motor, about which we have heard some remarks, has been realized.

MR. VANKIRK—I think the President made a little mistake which I will take the liberty to correct. It was the mo-

tors which worked 23 hours per day and not myself. Some three years ago the management of the Westinghouse Air Brake Company concluded to change their method of handling power, believing that the steam engines were not as economical as motors, they decided on electric transmission in conjunction with alternating current motors—two phase. In their central power plant they also went a step further than the steam engine and installed steam turbines. Three 600 H.P. turbines were put in, these turbines making 3,600 revolutions per minute—a rather high speed. Desiring to ascertain the relative economy of the motor drive in changing from steam to electricity, the company did not disturb the old steam plant, but made some very complete and exhaustive tests covering two or three weeks' time. After working up the data secured during these tests it was found that the use of the motors driven electrically from a central power station effected a saving of about 33% in coal, not taking into account the extra labor required to look after the engines, etc., and loss in steam lines. There is available considerable data on this subject which I did not have time to gather up and put in logical form, and, as Mr. Scott has stated, there has been such a demand upon my time that I could not do the subject justice. I am going to take the first opportunity, however, to put it before you if I have another such opportunity.

THE USE OF THE ELECTRIC MOTOR IN MODERN BLAST FURNACE PLANTS.

BY ANDREW ELLICOTT MACCOUN.

In the large blast furnace plants of to-day electricity is gradually taking a very important part in the economical operation of all labor saving devices for handling raw materials, such as ore, coke and limestone.

This is largely due to the great convenience and economy in transmitting it, the ease and convenience of control and the great economy over uneconomical steam engines which is effected by its use.

Most of the power houses for these plants have their steam boilers supplied by the waste blast furnace gases, no additional fuel being required; the bosh water which is circulated around the tuyerers and cooling plates of the furnaces can be used as condensing water, so that power can be generated very economically as the power plants for this purpose generally use compound condensing engines of good steam economy.

Large electric ore bridges are used in the stock yards of these furnaces for handling all the raw materials, and these operate in the cheapest possible way, unloading and storing it in the stock yards so that large supplies of all the different grades of ore can be kept on hand. As the furnaces require the different ores, grab buckets on the bridges take it from the piles and dump it in the ore bins ready for use in the furnaces.

Electric car dumpers also are being used extensively for dumping the railroad cars in which the ore and other raw materials are received into smaller cars more suitable for being unloaded from the ore bridges into the stock yards; electric locomotives are used for shifting these cars, and in many places they are also used for shifting the railroad cars in which the ore, coke and limestone are received, over the bunkers for di-

rect use on the furnaces. These electric locomotives are much more economical than the steam shifting locomotive and much fewer repairs are required on them. Small electric cars or larys are also used extensively for delivering the raw materials from the ore, coke and limestone bunkers directly to the furnace skips.

The labor for handling these raw materials has been reduced to such an extent by these labor saving devices, that it is surprising to see how few men are required in the stock yards of the modern furnace plants where such enormous quantities of raw material are continually being handled.

There are many other places around blast furnaces where the use of electric motors also play a very important part, such as on metal mixers, in the running of machine shops and carpenter shops, tilting of hot metal ladles, and running of electric cranes for handling pig iron, on cranes for skulling ladles, and on skull-crackers for breaking up scrap. For work of this character the electric motor gives by far the most satisfactory results, and there are many places where their application has reduced the labor force required to a quarter of what it formerly was when the steam engine was used, and the investment has paid for itself in less than a year.

Motors are also used to advantage in running pig machines; these consist of endless conveyors with molds in the shape of an iron pig, into which the molten iron is poured and cast into pigs which fall from the conveyor into cars ready for shipment; these machines have saved much hard labor around blast furnaces which formerly required large cast-houses attached to them in which the iron could be run into molds; but now it is run from the furnace directly into ladles, and if it is not to be converted directly into steel it is poured on the pig machine and cast into iron pigs.

In all work of this class scattered over large areas the electric motor is by far the most economical thing to use; outside of its gain in economy over the steam engine, the condensation

in long steam lines is avoided and often small boiler plants have been done away with, and labor, fuel and repairs have been saved. And as the electric motor requires very little attention it can be readily seen what enormous savings are effected by its use in such places.

Electric hoists are also gradually coming into use for hoisting the raw material to large furnaces; these with the modern skip equipments save top fillers on the furnaces and and also are much more economical than the steam engine used for this purpose.

I will mention a few of the advantages gained by the use of electric hoists and will make a few comparisons between the hoists operated by steam and by electricity.

The modern skip equipments are made very much larger than the old style hoists, lifting from 5 to 10 tons of raw material at from 250 to 400 feet per minute; with large furnaces this is very important, for at times when a furnace is running badly it is very important to fill it quickly, thus not allowing the burden to get very far out of reach; but with the older style elevator which took up two barrows or so at a time, it took a long time to fill a furnace in this condition, and furnaces always work much better when such irregularities are avoided.

The steam hoisting engines used for this purpose are very uneconomical, using about 150 pounds of steam per horse power hour.

Automatic cut-off engines have been tried repeatedly in many places, but in all cases that I know of they have been failures, and were replaced by the old style engines, as the automatic cut-off engines would not make the exact stops required for this class of work.

The electric hoist can be made to stop at exactly the same point in its travel, independent of the load carried. This is done by the means of series of magnets that control switches arranged to cut in more resistance when the motor starts to

slow down near the end of its travel, on the light loads than on the heavy loads. By adjusting these magnets, the hoist can be made to stop at any point, independent of the load carried.

In addition to the great steam consumption of the steam hoist, there is a far greater loss due to the condensation going on in the long steam lines that generally run to these hoists, and in the exposed valve chests of the engines. These losses in twenty-four hours amount to considerable, and there are always more or less leaks in steam lines of this character; besides this there are often long intervals during which the engines stand idle, yet all these losses are continually going on. There is also a great quantity of cylinder oil, and engine oil, and packing continually being used by the steam hoist. These items amount to a great deal during a year; but with the electric hoist the bearings are self-oiling and use very little oil, and require very little attention. At some works where these hoists are used, the man that runs the hoist also weighs the ore and limestone, and operates the bells on the furnace, the hoist being entirely automatic after it is once started.

From actual tests on one of these furnaces, the average efficiency (the ratio between the theoretical mechanical horse power required to lift the material and the electrical horse power taken by the motor), is approximately 61%, when the efficiency is averaged with all the different loads, such as ore, coke and limestone. This efficiency takes into account all the losses in motor and gearing, friction of skips on tracks, and is the average of a great number of readings taken from all the different loads.

An additional test was also made from Wattmeter readings, the Wattmeter being very carefully calibrated.

The Wattmeter readings were taken for two weeks on a line on which there were three blast furnaces; two of the above furnaces were identical in size, the third was smaller.

Forty-eight horse power was the average power consumed by these three furnaces during this period.

Eleven horse power was the part of this power estimated as used by the small furnace.

Eighteen and five-tenths horse power was the power consumed by each of the larger furnaces.

Ten thousand tons of raw material was the approximate amount lifted to each of the larger furnaces each week during this period, and 135 feet was the height material was lifted.

Nine and one-tenth horse power was the average theoretical horse power required to lift this material to one of the larger furnaces during this time.

Fifty per cent. is the approximate efficiency or ratio between the power used at switchboard in power house, as shown by the Wattmeter and the theoretical horse power required. This takes into account all losses in lines, motors, gearing, friction of ropes, drums, sheaves and extra trips when no load is carried, and movements made for lifting scrap.

If an electrical horse power hour is generated at switchboard in power house for 20 pounds of steam, then taking all losses into consideration it takes 40 pounds of steam per horse power hour to do the actual lifting at the hoist.

The steam hoisting engines take over 150 pounds of steam per horse power hour, and this does not include any losses such as friction, condensation in steam pipes and valve chests, and it can be readily seen how great losses these are when they are properly considered.

If the value of an electrical horse power for a year at switchboard is placed at $50.00, the cost of power of one year at one of the larger furnaces would be approximately $925.00; at this rate, therefore, the cost of power for lifting 100 tons of material 135 feet would be $17\frac{8}{10}$ cents, and the cost of lifting one ton of material the same height would be $\frac{1}{6}$ of a cent. There are very few steam hoists at blast furnace plants that will do this work for one cent per ton.

This shows plainly in one instance the great economy effected by the use of the electric motor on furnace hoists, and

this is only one of the smallest savings, because as a usual thing in other classes of work there are great savings in labor besides the savings in power, and at times one man can be put to manipulate the same number of motors where formerly it took two or three men when engines were used.

These facts show how the use of electricity is being developed about steel works and blast furnaces, and there are many of these works that have over 10,000 horse power of motors of various sizes for work of this kind, and there are gradually increasing applications of electricity to many other classes of work.

THE PRESIDENT—Mr. F. M. Duncan, of the Akron Electrical Manufacturing Company, on "Machine Tool Driving." As Mr. Duncan is not here this evening, his paper will be read by Mr. Hirsch.

ELECTRIC EQUIPMENT IN MODERN MACHINE SHOP PRACTICE.

By F. B. Duncan, Akron, Ohio,
General Superintendent Akron Electric Mfg. Co.

As the steel and iron industries are the vitals of the manufacturing interests of the country anything which promises increased efficiency in our shops is worthy of being given the closest investigation, and of having the best engineering talent devoted to the solution of the questions involved.

Of the many changes electrical machinery has introduced in manufacturing, a very important phase is the part it plays in the equipment of the modern machine shop.

The traction field has been fairly well worked over; standard lines of apparatus, both mechanical and electrical have been evolved, and there is at the disposal of the capitalist entering this field a well defined system as to type of generators, motors, controllers, transmission lines, etc., and all that remains to be done by the engineer in charge of any particular installation is to have made the slight modifications necessary to suit local conditions.

Turning to the metal working industries (which are incomparably of more importance to the country, both from the amount of capital invested and from their relation to our national prosperity and supremacy) progressive manufacturers everywhere are installing electrical transmission in their plants, and yet most take up the question, especially in machine shops, only to find it is impossible to obtain anything like a complete shop equipment of tools with individual motor drive, and what can be obtained is a sort of half-breed compromise between a belted outfit and an electrically operated one; while in the smaller sizes of tools it is practically impossible to obtain anything pertaining to an electrically driven equipment.

as tapping machines, bolt cutters, pipe cutters aud pipe threading machines, power shears, emery wheels, grind stones, buffing apparatus, foundry blowers, etc., that require very little variation in speed, not more than can be readily obtained by shunt field regulation.

There are a number of serious difficulties on the mechanical side, but they are incidental rather than fundamental, and therefore by the expenditure of capital and engineering talent can be readily eliminated.

Some of these are the following:

1st. The present design of machines for belt operation necessitates new patterns for many parts before they can be electrically driven.

2d. The greater first cost as yet of motor driven tools.

3d. That the present design of many tools is not heavy enough to stand positive motor operation.

4th. The large demand as yet for belt drive machines compared with that of electrically operated ones, and the reluctance of manufacturers to be the pioneers in what is as yet commercially an untrodden path.

It is not the writer's intention to go into the engineering or business details of this question, but simply to indicate methods that have been used, and can be used again on a broader scale to overcome these obstacles to what is an ideal method of power transmission.

Speed variation on the electrical side of the question is the most serious of all these problems, and must be given most serious consideration if anything is to be accomplished. There are a number of well known ways to obtain the desired variation of speed, some of them purely electrical, and others partly mechanical; to the latter class belongs the single voltage system with shunt field regulation. By this means there can be obtained electrically not more than one-hundred per cent. increase above the normal, the other changes must be accomplished by means of gearing or some other mechanical method,

unless we consider in this connection the double commutator motor.

The single voltage system has one distinct advantage, which is, that a power plant can be installed of the same voltage as the local power service, and for overtime work it enables a manufacturer to dispense with the service of an engineer and fireman and the attendant losses from operating his generating machinery at night, or if power is furnished cheap enough to dispense with his own generating station entirely. It also permits a shut-down for repairs of boilers or other generating apparatus without disturbing the operation of the factory as a whole. Its disadvantages are the fact that if any great range of speed is to be obtained electrically, a double commutator must be used, the additional space required for this design in the tool construction and the multiplying of the care of the commutator and brushes.

The multi-voltage system is a method which furnishes the desired variation in speed by electrical means alone. This system in the sense of four or more voltages solves the question of speed variation, but introduces some serious disadvantages. Among them is the complicated generating set, switchboard, controllers, installation, and the larger first cost of same. Another is the inability of ecconomically operating the plant from an outside source of power. There are other objections to this system which might be mentioned, but it is not the purpose of this article to enter closely into the question.

There are some objections to each of these systems, and as the settling on standard practice for shop equipment is the first question to be determined before any real progress can be made, the consideration of this matter should be therefore seriously undertaken by our engineers, and a little of standard practice worked out.

A compromise between the two systems above mentioned, which would combine many of the advantages of both, is the common three-wire system using field regulation between the

steps and for an exceptional tool needing very wide speed variation, the use of a double commutator motor. For compact plants could be used the 110-220, and for more scattering or larger plants the 220-440 volts transmission; (lamps can, of course, be used at 110 or 220 volts as the case might require. Across the outside wires, planers, grinders, blowers, buffing machines, and wood shop apparatus, etc., would be connected, as in general they do not need any more variation than can be obtained by the shunt field. Lathes, boring mills, milling machines, drill presses, etc., would be operated from either voltage at will, and speed between steps of voltage be obtained by field regulation).

The present is an opportune time to take up this question of machine tool drive as the advent of the Taylor White and other similarly treated steels with the attendant heavy duty and high speeds are necessitating a complete redesign of most of the machine tools now built, because they are not heavy enough to stand the strain resulting from the use of this steel, and the belts and pulleys of dimensions as now used simply will not transmit the power required.

Motor drive by means of a motor geared to the tool furnishes the positive drive necessary to the practical use of these steels, and also (through the circuit breaker) provides an adjustable release which obviates the necessity of a "slipping point" in the tool itself such as is now provided in the belt driven machine tools, and which point is in many machines away below where it should be, in order to get the greatest efficiency from the tool.

Many of the difficult problems attending machine tool drive are being solved, one of the last and most important advances in this line being the entire elimination of belts and pulleys in planer operation. Direct connected motors and magnetic clutches being the solution of this difficult and what was for some time one of the most difficult has now become the easiest machine to operate electrically without belts or countershafts.

A brief setting forth of the advantages pertaining to individual motor operation of tools is given below:

1st. Greater output per machine due to positive nature of drive; in many cases this is at least fifty per cent.

2d. Ability to accurately determine by means of recording instruments centrally located with a multi-point switch whether tools are being kept at work in proper manner, thereby affording a graphic record of the time each machine is in operation, and its consumption of power. This will also enable the detection of tools that are in bad condition due to abnormal friction of bearings or moving parts.

3d. The flexibility of placement of machine tools to suit the passage of the work through the shop.

4th. Better light and absence of dirt due to belts, shafting, pulley hangers, etc., and less first cost of building owing to the lighter overhead construction permissible when no shafting pulleys, hangers, or belt tension have to be taken care of.

5th. Free head room for crane service.

6th. Ability to shut down or start up any one machine independently of all others.

It is the writer's opinion that the individual method of operation will obtain in smaller units until even the very smallest tools can be so obtained, and the crying need of the hour is an electro-mechanical tool concern that will devote its entire energies to this field and design and build a complete line of electrically driven apparatus with this method of operation alone in view. There is needed a complete line of drill-presses, lathes, milling machine, planers, boring machines, both horizontal and vertical that would enable progressive manufacturers to install a complete individual motor driven equipment, which, at the present time, is practically impossible.

The market for this apparatus would at present consist of two classes of customers.

1st. Those who desire a plant that will produce work in the most economical manner, and are willing to pay for it.

2d. Those who wish to equip a small shop without going to the expense of installing boilers, engines or shafting.

The power consumption in a plant of this kind would be smaller than in a belt driven one, but that question after all is a minor one. The efficiency of the tool installation in reference to the amount of work turned out and the final cost of such work is the primary and great object to be kept in view.

The prospect is so alluring that strenuous efforts should be made by electrical engineers to meet the conditions, as it is on their side that the fundamental difficulty lies, and there should always be kept in view that golden age condition of a unit power station operated for all the manufacturers of any locality and power furnished by it to all, thus abolishing the abominable system now in vogue of hundreds of small generating plants with their attendant lack of economy and unreliability.

This is an end worth looking forward to, but it will need much "strenuous life" on the part of both the business element and the engineering fraternity before is obtained the inestimable privilege of closing the switch at any time of night or day and having at disposal unlimited power with practically no possibility of a shut down in combination with the unrivaled efficiency in production of work of a motor driven tool.

Appended to this paper is a sheet giving motor power required by a number of the standard makes of tools in general use by machine shops of this country.

DATA SHEET OF MOTOR POWER ON STANDARD MACHINE TOOLS.

No. 1.

Description of machine, Planer.
Make of machine, Niles Tool Co.
Size of machine, 10 ft. x 10 ft. x 20 ft.
No. of cutting tools, 3.
Size of cut, $\frac{3}{4}$ in. x $\frac{1}{8}$ in. each tool.
Cutting speed, 18 ft. per minute.
Material machined, cast iron.
Weight on platen, 40 tons.

Power for cut, 26.54 H. P.

Power for reverse, 42.93 H. P.

Power for return, 23.56 H. P.

Ratio of return, 3 to 1.

Method of drive, Motor belted to counter shaft.

Kind of Motor, D. C. Compound wound.

Remarks:—Not enough flywheel effect on countershaft to equalize load at moment of reversal. A 30 H. P. motor was used for above drive with good results.

No. 2.

Description of machine, Planer.

Make of machine, Pond Machine Co.

Size of machine, 8 ft. x 8 ft. x 20 ft.

No. of cutting tools, 3.

Size of cut, $\frac{5}{8}$ in. x $\frac{1}{8}$ in. each tool.

Cutting speed, 18 ft. per minute.

Material machined, cast iron.

Weight on platen, 32 tons.

Power for cut, 16 H. P.

Power for reverse, 28.15 H. P.

Power for return, 14.80 H. P.

Ratio of return, 3 to 1.

Method of drive, Motor belted to counter shaft.

Kind of Motor, D. C. Compound wound.

Remarks:—Not enough flywheel effected on countershaft to equalize load at moment of reversal. A 25 H. P. motor was used on this machine with good results.

No. 3.

Description of machine, Planer.

Make of machine, Pond Machine Co.

Size of machine, 66 ft. x 60 ft. x 12 ft.

No. of cutting tools, 2.

Size of cut, $\frac{1}{2}$ in. x 1-16 in.

Cutting speed, 21 ft. per minute.

Material machined, Open hearth steel castings.

Weight on platen, 4 tons.

Power for cut, 10 H. P.

Power for reverse, 16 H. P.

Power for return, 14 H. P.

Ratio of return, 3½ to 1.

Method of drive, Direct current compound wound motor, mounted on housing of planer with 42 in., 1500 lb., flywheel running at 400 R. P. M., mounted on motor shaft. Flywheel used as driving pulley for return of platen.

Remarks:—A series of recording ammeter cards taken on this planer showed it was idle an average of 2½ hours per day, showing a saving of power by use of individual motor drive. The above 2½ hours was generally made up of short periods for setting work, taking measurements, etc.

No. 4.

Description of machine, Planer.

Make of machine, Gray.

Size of machine, 28 in. x 32 in. x 6 ft.

No. of cutting tools, 1.

Size of cut, ¾ in. x ⅛ in.

Cutting speed, 22 ft. per minute.

Material machined, cast iron.

Weight on platen, 3 tons.

Power for cut, 3.1 H. P.

Power for reverse, 4.4 H. P.

Power for return, 3.8 H. P.

Ratio of return, 4 to 1.

Method of drive, D. C. compound wound motor mounted on platen housings with flywheel 30 in. diameter 496 lbs., 800 R. P. M , mounted on motor shaft and used as pulley for return of platen.

Remarks:—Average load on motor 2.48. A 3 H. P. Motor at 800 R. P. M. gave first rate-service. Rheostat used in series with shunt field to raise cutting speed on light work to 30″ per minute.

No. 5.

Description of machine, Turret Lathe.

Make of machine, Gisholt Machine Co.

Size of machine, 28 in. swing.

No. of cutting tools, 5.

Size of cut, $\frac{3}{4}$ in. x $\frac{5}{16}$ in. 1 tool, $\frac{1}{2}$ in. x $\frac{5}{64}$ in. 4 tool.

Cutting speed 25 ft.

Material machined, Tropenas cast steel.

Power for cut, 3.9 H. P.

Weight of casting, 400 lbs.

Method of drive, D. C. compound wound motor 600 R. P. M. geared to headstock gear in place of cone pulley. Speed variations on motor 100% in all 25% by armature control below normal and 75% increase above normal by resistance in shunt field. Eleven points in controller giving with the three gear speeds, 33 changes of speed in all. An increase in output of 100% was obtained on this machine by changing from from belt to geared motor drive.

No. 6.

Description of machine, Drill-press.

Make of machine, W. F. & John Barnes.

Size of machine, 21 in.

Motor power required, 1 H. P.

Method of drive, D. C. compound motor mounted on frame of press and belted down to driving pulley. Starter and reversing switch mounted on frame of press within reach of operator seated at table.

No. 7.

Description of machine, Radial Drill-press.

Make of machine, Niles Tool Works.

Size of machine, No. 1, 5 ft. arm from center of column.

Motor power required, (max.) 2.03 H. P.

Size of motor used, 2 H. P. 600 R. P. M.

Method of drive, Vertical D. C. compound wound motor mounted on top of column and geared to driving shaft. Rawhide pinion used on motor shaft.

No. 8.

Description of machine, Double end emery wheel stand.

Size of wheel, 18 in. x 2 in. wheels.

Speed of wheels, 950 R. P. M.

Kind of work, 2 laborers grinding castings.

Maximum H. P., 6 H. P. momentarily.

Average H. P., 3.5 H. P.

H. P. motor required, 5 H.P. open with dust proof covers.

Method of drive, D. C. compound wound motor mounted on grinder shaft between the wheels.

No. 9.

Description of machine, Vertical Boring Mill.

Make of machine, Pond Machine Co.

Size of machine, 10 ft. table.

No. of cutting tools, 2.

Size of cut, $\frac{3}{4}$ in. x $\frac{1}{16}$ in.

Cutting speed, 20 ft. per minute.

Material machined, cast iron.

Weight on table, 3.5 tons.

Motor power required, 8.58.

Method of drive, D. C. compound wound motor belted to countershaft. Twelve H. P. motor gave good results on heaviest cuts and weights of castings.

No. 10.

Description of machine, Slotter.

Make of machine, Bement & Miles.

No. of cutting tools, 1.

Size of cut, $\frac{3}{8}$ in. x $\frac{1}{16}$ in.

Speed of tool, 20 ft. per minute.

Material machined, Open hearth steel castings.

Motor power required, 6.98 H. P.

Method of drive, D. C. compound wound motor belted to countershaft.

No. 11.

Description of machine, Flat Turret Lathe,
Make of machine, Jones & Lamson.
Size of machine, 2 in. x 24 in., their standard.
Motor power required, 1½ H. P. for satisfactory service.

No. 12.

Description of machine, Tool Grinder.
Make of machine, Gisholt Machine Co.
Size of wheel, their stand cup wheel.
Speed of wheel, 16 to 18 R. P. M.
Maximum H. P. required, 7 for short periods.
Average H. P. required, 4.

Method of drive, D. C. compound wound enclosed motor mounted on grinder shaft with field rheostat in series with shunt coils to increase speed from 1600 to 1800. A 5 H. P. open motor with enclosing covers gave good satisfaction on this grinder.

No. 13.

Description of machine, Engine Lathe.
Make of machine, Hendey Norton.
Size of machine, 16 in.
Motor power required, approximate, 2 H.P. at maximum.

Method of drive, D. C. compound wound motor mounted on support, bolted to bed of lathe and equipped with clutch and cone pulley with belt to headstock cone.

No. 14.

Description of machine, Engine Lathe.
Make of machine, Putnam.
Size of machine, 18 in. x 6 ft. between centers.
Motor power required, 2.1 H. P.

Method of drive, D. C. compound wound motor geared to countershaft.

No. 15.

Description of machine, Engine Lathe.

Make of machine, Pond Machine Co.

Size of tool, 36 in. x 10 ft. between centers.

Motor power required, 10 H. P.

Method of drive, D. C. compound wound motor direct geared to countershaft.

On all the above machines where motors are geared, rawhide pinions were used on motor shaft. Information as to motor H. P. required for tools not given above will be cheerfully furnished to those interested, as it is the writer's belief that the more generally such information is disseminated the sooner machine tool builders, motor manufacturers and machine shop proprietors will be able to solve the questions pertaining to the economical production of the machinery merchandise of the country.

THE PRESIDENT—The various papers which we have heard this evening present various phases of the electric motor problem. Mr. Hirsch, Chairman of the Program Committee, to whose efforts the number of papers this evening is largely due, has, by letter or conversation, invited a number of members generally to participate this evening, and we will be very glad to hear from some of these men. Mr. Fisher.

MR. H. W. FISHER—We are using electric motors in a few of our factories at the present time. At Perth Amboy, we use alternating current motors—three phase—and use them with a great deal of satisfaction. I think the only trouble which developed was a hot-box which had to be rebabbitted. In our Pittsburg factory we have used special dirrect-current motors. The only objection I see to the direct-current motor is the trouble with the commutator. Occasionally it sparks too much, and the commutator has to be turned down, which, of course, takes a little time to do. But in general these motors have run a good many months without having anything done to them. I think, however, that one or two

suggestions might be made to the manufacturers of motors and generators which would be of benefit to those who use them. I know of a case where a motor was set up according to directions ready to be operated, but the outfit had resistance in series with the armature. The motor, of course, sparked a very great deal, the resistance got very hot. Several positions of the brushes were tried but in every case the resitance heated. Then one of the engineers of the Westinghouse Company was sent for and he very soon got the motor to running all right. It appeared that the brushes were not set right. A very little difference in the set of the brushes made quite a difference in the operation of the motor on account of the excessive amount of current going through it. It seems to me that when these motors are sent out a diagram or drawing should accompany them showing the approxmate position of the brushes, so that the comparatively ignorant person who has to set up the motor can probably get it right the first time.

THE PRESIDENT—One of the gentlemen requested to prepare one of the papers this evening is Mr. Friedlander, out at Duquesne.

MR. FRIEDLANDER—We have occasion to use some Westinghouse motors, and as in the case Mr. Wales speaks about we are entirely dependent on these motors. We have one 100 H. P., No. 39 motor lifting all the iron ore for four blast furnaces. This motor works night and day and lifts the mixture fifty feet high. From these furnaces the iron is sent to the different mills, so that if this motor gives out the mills are completely shut down. We have had this motor running about four years. Through a mistake of the crane builder we did not get the right motor in this place. A 100 H. P., railway-type machine was finally put in. We did not want to accept the machine, but we received a guarantee from the Westinghouse people that if the motor did not work in the service we had they would take it back. This motor does fifty

per cent. more work than we bought it for. Of course it has given us lots of trouble but it is still in there.

You can see in our place a spare armature provided with 30' pulley, 6' wide brake band, and pinion 10' wide face. The crane is 72 feet from the ground and the armature hangs on a chain block ready to go into the motor any minute day or night. It can be put in by a man who never saw a motor, and he can place this armature in the machine inside of 40 minutes, it took three hours in the beginning. We have run this motor about two years without five minutes delay to the mill. We have not got room to put a bigger motor in. I have made tests of this motor and it is actually doing 100% more work if the ladle is full of iron. The motor is of the high-speed type, making about 1,100 revolutions per minute, and we have considerable trouble in keeping the winding on. It hoists up a ladle containing a 50 ton load to a height of about fifty feet. Any time in running down this ladle the motor can be stopped at the will of the operator. It can be stopped within two or three revolutions. Of course, this is very hard on the armature shaft. We have bent two or three armature shafts. I do not think our work can compare with street car work. Most of our men are not experienced with motors. There are men there who have never been near a motor. We have to have a controlling device with the machine so they can run it. Of course they do not look after the machinery at all, and in consequence the motors see very hard service You can see many of our motors with lugs broken off, break shaft bearings broken off—troubles due to suddenly reversing the motor when running at considerable speeds. These are all mechanical troubles. I have seen the bolts holding the motor sheared off ; some of them 2" bolts and still they break. If any kind electrical man takes the pains to come down to our works I can give him a week's board and room and tell him about my troubles. I think in the future when we have done away with all these troubles that we will not be able to get motors fast enough.

MECHANICAL SPEED CHANGING DEVICES. DRIVING MACHINE TOOLS FROM CONSTANT SPEED MOTORS.

BY MR. H. M. PALMER.

With the introduction of the electric motor as a drive for machine tools, the problem of speed control has been solved for many, by equiping individual tools with variable speed motor drive; but a study of construction of and conditions under which a machine operates, shows advantages in the use of a constant speed motor with a speed changing device.

The latter method has met with some disfavor, as it is claimed an uneconomical output results, due to a waste of time on the part of the operator, who is unable to properly adjust cutting speed of tool between adjacent steps of cone pulley or gears.

As a matter of fact, there are considerable increments of speed change in the usual design of tools, but is it necessary for the operator to waste time in this direction?

The design of machine tools has been such that each is capable of doing the work economically between determined limits for which it was intended.

It would seem that the ineconomy, if any, would result more from a waste of time only when the tool is operated wholly out of its range; for it appears that each machine is designed to take care of the work within certain increments of speed. This being the case, it is evident that the output does not depend so much upon a certain speed, but largely upon the quality and temper of cutting tool, depth and width of cut, grinding and setting of tool, and upon the manner in which power is applied.

Output may be expressed by weight of metal removed by cutting tool per kilowatt hour.

It may interest many to learn that the economical output is dependent mostly upon the speed and upon the quality and temper of cutting tool which governs the speed.

The general construction of machine tools has been much the same for years, but with added improvements from time to time, which have largely increased the ease of operating and efficiency, the essential features of design have been such as to fulfill requirements.

Many tools require but one speed, while a few, such as boring mills, radial drills and lathes are best operated by variable speed changes.

In practice the speeds obtained by the use of cone pulleys and gears on lathes and drills are in general sufficient; but for large boring mills a full range of speed between limits fixed by the size of machine is desirable to accommodate extreme and constantly varying radii of cutting tool. The Reeves' pulleys, the most effective device of its class, is designed to give such a speed range.

The most practical conditions of machine tool operation have been determined from years of experience, and variable speed devices employed are such as to give satisfactory results. Otherwise builders would have incorporated in their designs much better ranges of speed.

With little alteration in the construction of tool add the proper mechanical speed changing device where necessary, and apply the constant speed electric motor as a drive.

For this purpose the alternating current induction motor, a mechanically simple machine, is admirably adapted.

The quality and temper of cutting tool and material to be worked are limiting conditions of its speed, which is inversely proportional to weight of metal removed; so that for any reasonable speed obtained by speed change, is an equivalent to cutting speed results, by properly adjusting the feed of tool and size of cut, or is the removable of as much metal as will still maintain the inherent properties of the tool.

Consider a lathe having cone pulleys in which it is proposed to turn off a cylinder of cast iron, and it is found that the nearest to customary speed on one step of cones is à little fast, and on adjacent step a little slow for usual cut.

A compensation may be made here by running on each speed with its maximum cut, both runs producing a like result, which is equivalent to having a middle speed from a variable speed motor or otherwise, and a cut the average of former two. Or the products of speed, times, size of cut or weight of metal removed, in each of the three cases are equal and represent the work done, or weight of metal removed per kilowatt hour, when reduced to these units.

The work done depends largely upon the quality and temper of cutting tool, and if these properties be increased, the speed can be increased proportionately with corresponding increase of output.

It is quite possible to obtain these results to a marked degree, and time only will reveal the fact.

Change of speed for the most part is made to accommodate the different cutting radii between practical limits, and are designed to suit conditions of machine operation.

PAPER BY MR. G. E. FLANAGAN.

It sometimes happens that an appliance developed for a special service exhibits certain general characteristics which render it useful in various ways other than those for which it was intended. The improved form, standardized type, and comparatively low cost of the modern street car motor—advantages which have been attained through the great demand for car service—have rendered this form of electrical machine available for many purposes besides that for which it was originally designed. Prominent among these is the electric traveling crane, the requirements of which are in many respects similar to street car service; some of the demands common to both being powerful starting torque, capacity for enduring an over-

load for a short time, and close speed regulation under varying loads by means of controlling rheostats. These qualities are exhibited to perfection in the series wound machine, of which the street car motor is a leading type, the speed of which is governed to a great nicety by the introduction of a variable resistance in series with the motor. This motor will run fast or slowly according to the work it is doing, in fact its rotative speed will increase until the armature destroys itself if the load is removed and no resistance placed in circuit to correspondingly decrease the flow of current. The motor is geared so that its normal speed under the given load will closely approximate what is desired for the longest runs, and the speed naturally falls when the load increases; while for decreasing loads and for starting, the controlling resistance is introduced into the circuit. The motor quickly attains its normal speed, corresponding to the load, and the counter electromotive force set up automatically reduces the current, allowing the resistance introduced for this purpose to be cut out. The impression still prevails in some quarters that this method of control costs as much as running the motor under full load, but this is by no means the case. When the speed falls under the influence of the load, the motor is taking additional current for the reason that the counter electromotive force becomes weaker, and there is less internal resistance. When outside resistance is placed in circuit, the reverse is the case; the sum of the electrical energy then taken by the motor and that wasted by the resistance coils is only a fraction of what is required for full load.

The electro-magnetic brake is an important feature of all cranes. Starting the motor releases these brakes, while the instant the current is cut off the brake applies itself.

The application of street car motors to the driving of mill tables is another instance of their usefulness, replacing in this service a very uneconomical type of reversing engines. These engines are so constructed as to be very extravagant in the use

of steam, every refinement being sacrificed to simplicity and the ability to withstand abuse. The street car motor attains these desirable features at a less cost. It is strongly constructed, of the inclosed type, practically dirt proof, and will work with a minimum of care and attention. For this reason they are especially suitable for mill tables, foundry cranes, or for use in other places where a defence must be made against dust and dirt. The lifting tables, or tiling tables used in connection with three-high mills have generally been driven by a small reversing engine through a system of gears, including a floating idle wheel carried on a pair of lever arms pivoted to a fixed shaft and to the side shaft on the table. This gear train can be dispensed with by attaching the motor directly to the moving table, the power transmission then being electrical through the wire, in place of mechanical through gearing.

For working under a fixed load where a uniformity of speed is desirable, the shunt wound motor is available, while the compound wound machines combine some of the advantages of both the other types.

That a small motor is a readily portable machine is a fact which is becoming fully appreciated. The connections for power transmission are easily and quickly made at a very slight expense. That the cleaner and cooler the machine is kept the better will be the result is also well known, but this knowledge is not always acted upon; while the attempt to keep an open field type of motor clean by covering it with a wooden box has several times proved disastrous, although this may be done where the motor runs intermittently. A motor in use gives off considerable heat and this must be dissipated, by air currents or otherwise, while radiation should be free and unobstructed.

The President—Mr. W. F. Lamme expected to be present this evening. He has been abroad during the past year, and in that time has visited the steel works at Antwerp. These works have been equipped with an alternating current plant and one of the notable features is that heavy rolls are

operated by motors—some of 350 and some of 425 H.P. It is a little notable that the first large rolls driven by motors have been by motors which come from Pittsburg, right in the midst of our steel and iron work, and have gone into a mill in Antwerp.

The subject is open for general discussion and there should be a number here who can contribute points of interest.

A MEMBER—There is one point which strikes me has not been touched upon. Suppose we have a shop which contains a great many small machines. Is it cheaper to drive each machine individually with a small motor or put up shafting and drive the shaft by motor? I believe every one who knows anything about it at all knows that motors are considerably more economical, so far as the consumption of power goes, than shafting, but when we get down to small motors the efficiency decreases. In other words, a two horse-power motor does not cost us double what a one horse-power does. The whole matter seems to me to come down to a case of fuel. Some concerns in the east have put in a number of small motors as low as one-third H.P., and as the cost of fuel there is quite high they effect quite a saving. I think, however, it would be poor engineering to do that here where fuel is cheap.

There is another point which, it seems to me, has not been touched upon, and that is the question of the application of motors to pumps. I noted in one of the papers the statement made that hoisting engines used 150 lbs. of steam per H.P. per hour. This is not at all remarkable. I have seen pumps use as high as 300 lbs. on tests. If a H.P. costs $50.00 per year, which I think is a fair average, you might have $500.00 per year cost of this pump if it used 30 H.P. If a motor uses 150 to 200 lbs., I believe it would cost $3,-000.00 a year to run the pump. A number of pumps on a plant are quite wasteful. I believe there is quite a field here for applying the motor in place of the steam cylinder—by a direct connected pump—driving by motor as electricity is com-

you will find the efficiency of the motor is much reduced when you get down to the small sizes.

MEMBER—It seems to me more a question of fuel. You know the first cost and you know the depreciation, and you know the cost of repairs. It is a mere matter of figuring out your fuel bill. There have been a good many tests published during the past year by the American Society of Mechanical Engineers covering the efficiency of small motors. It is something you can sit down and figure out to a certainty.

THE PRESIDENT—A gentleman who has had a great deal to do with the practical use of motors from an engineering standpoint is Mr. P. N. Jones, who has just come into the Society.

MR. JONES—I am but a baby in the Society as yet, and I hardly expected to have anything to say to-night. I think the question of motors has been very thoroughly discussed. There is only one point that I think of, and that is in regard to the different types of winding. I do not think these types are selected as they should be, especially for some classes of mill work. I find in use series wound motors having controllers for running in one direction continuously; and for roll-table work compound wound motors are much better, because the series motor has been easy to gear up to anything they have been in the habit of making use of them. The compound motor is like the throttling engine with governor which permits the speed to drop when the load comes down, and like the engine, has a speed above which it can let go. This is the only suggestion I have to offer.

MR. FLINT—In connection with the rather indefinite subject of the distribution of power by means of electric motors, I would like to call attention to a plant which I saw two years ago in Franklin, where they have two 125 H.P. gas engines in their power house, and distribute power to a great many small machines around through quite a large sized factory. I remember one instance which came especially to my attention

as the open type motor. Recently I received a letter from the Westinghouse Company in regard to this matter. It was a question of drive in a galvanizing plant—either steam or electric. In this plant we have a very damp place ; also fumes from the acid vats. I had asked if a dust proof motor would be practical in this installation and if they could be thoroughly protected ; and was advised that such a motor entirely enclosed would be cut down in efficiency about 30 per cent. The consequence was that I placed the motor outside of the building and used an open type machine. Is it a fact that the efficiency of the closed type motor is less than the open type.

A MEMBER—I think I wrote that letter. I merely stated that a 30 H. P. motor would give about 18 H. P. if entirely enclosed.

THE PRESIDENT—In other words, the motor would have to be run at a less out-put and with a less production of heat in order not to get it too hot. The out-put of a certain size would be reduced, but the efficiency would not be materially different.

THE PRESIDENT—Mr. Dick has given some attention to this subject.

MR. DICK—Perhaps a word may not be out of place regarding motors for machine tool drive. So far as the kinds of motors are concerned, manufacturers are prepared to furnish either variable speed motors or constant speed for use with some form of mechanical speed changing device as the custo mer may prefer. I believe, however, that the present tendency is more and more towards the variable speed motor. I do not think, however, that any fixed rule can be laid down for all classes of work. Each motor or type of motor has a class of work to which it is best suited. A careful study of conditions, kind of work, etc., in any installation, must determine what is most suitable for that particular installation.

Mr. Duncan in his paper read to night, speaks of the difficulty of getting a variation in speed with direct current motors.

We have no trouble in doing this ; in fact, are doing it every day. It is done by varying the shunt field strength and with a properly designed motor, the results are admirable. By using this method, which is the one giving the most efficient performance, a variation in speed of 3 to 1 can be readily obtained on a single voltage circuit. If a greater variation than 3 to 1 is required, 2 voltages are used, obtained from a 3 wire system, giving usually 110 and 220 volts. With the 2 voltages a range of 6 to 1 can be obtained. The motor is first started on the lower voltage and speeded up to a certain limit by changing the shunt field current. Then the motor is switched over to the higher voltage and further increase the speed to the desired limit obtained by again changing the shunt field current. It is also possible, equally as well, where 3 wire circuits are not available, to use a motor with two commutators and obtain a speed variation of from 6 to 1. In case a still greater variation is necessary, a range of 9 to 1 can be obtained by using a 2 commutator machine on a 3 wire system. A speed variation of 6 to 1, however, seems to meet the usual requirements of machine tool drive.

Meeting adjourned at 10:50 P. M.

C. W. RIDINGER,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held Thursday evening, April 17th, 1902, in the rooms of the Society, the chairman, Dr. K. F. Stahl, presiding.

The minutes of the last meeting were read and approved.

For the Committee on Chemical Literature, Mr. Mohr read a paper translated from the German, published in "Stahl und Eisen" on the "Composition of Blast Furnace Slags."

The paper of the evening, on "Methods of Glass Analysis," by E. C. Uhlig, was then read.

THE ANALYSIS OF GLASS.

BY EDW. C. UHLIG.

Determination of $Si O_2$ $Al_2 O_3$ $Fe_2 O_3$ $Ca O$ $Mg O$.

Finely pulverize about 5 grams of the glass, first crushing it in a steel mortar, and after removing with a magnet any particles of steel, finish the pulverization in an agate mortar. The powder must contain no gritty particles and must feel almost like flour when rubbed between the thumb and finger.

Place the powder in a porcelain capsule, and allow to remain in an air bath at a temperature of 110°C for about a half hour. Transfer to a tightly stoppered glass tube.

Weigh out 1 gram and mix in a platinum crucible with 5 grams of a flux composed of 7 parts $K_2 CO_3$ and 5 parts $Na_2 CO_3$. Fuse over a bunsen burner, and when the fusion is liquid with no more CO_2 bubbles escaping, grasp the crucible with the tongs, and carefully place it in cold water to about one-half of its height. This will cause the fused mass to shrink away from the sides of the crucible, and render easy its removal with the aid of a glass rod.

When the crucible and contents are thoroughly cool,

transfer the button to a 500 c. c. porcelain casserole, and add enough water to cover it. Fill the crucible with dilute H Cl. (1 in 3), keeping the cover on, pour contents into a 100 c. c. beaker, and wash out the crucible with hot water, allowing the washings to run into the beaker.

Cover the casserole with a watch glass, and pour in the contents of the beaker, keeping the casserole covered to avoid loss by effervesence. Add sufficient concentrated H Cl. to dissolve the fused mass, and heat gently until effervescence has ceased. If the glass has been sufficiently pulverized, the fused mass will dissolve, and no flocculent silica will be discernible.

Evaporate to a pasty condition on a water bath. Remove from the bath and break up the pasty mass with a glass rod flattened at one end like a spatula. Place again on the water bath and continue heating with occassional turning over of the mass with the glass spatula, until the mass is nearly dry. Then grind up with a glass pestle, and continue grinding until the mass is about as fine as granulated sugar. Place the casserole covered, and containing also the pestle and spatula in an air bath, and heat at 120° C. until no odor of H Cl. can be perceived. This will usually take about half an hour.

It is very important to observe the above directions regarding the stirring or breaking up of the pasty mass in order to insure the complete removal of the H Cl. and dehydration of the silica. If the mass is not well ground, the H Cl. will sometimes remain, even after prolonged heating at 120° C.

Remove casserole from the air bath, and when cool add about 150 c. c. dilute H Cl. (1 in 3), add a drop of H NO_3, stir, wash off the pestle and glass spatula with hot H_2O and remove them. Filter and wash with hot H_2O.

If all of the above operations have been carefully performed, the filtration will be rapid and complete. It will not be necessary to use a filter pump. Continue washing with hot H_2O, until the last drops running through give no reaction with Ag NO_3.

Dry, ignite and weigh in a platinum crucible. Treat the contents with H_2SO_4 and H F., ignite over a blast lamp, cool and weigh again. The difference is $Si\ O_2$.

If any residue is left in the crucible, dissolve it in H Cl., and add solution to the filtrate from the $Si\ O_2$.

Divide the filtrate into two equal parts, make slightly alkaline with $N\ H_4\ O\ H$., boil gently and filter off the precipitated aluminum and ferric hydroxides. Dry, ignite and weigh the contents of one filter. This will give the weight of the $Al_2\ O_3 + Fe_2\ O_3$.

Dissolve the contents of the other filter in dilute $H_2\ SO_4$ (1 in 4), and allow the solution to run into a 100 c. c. Ehlenmeyer flask, wash filter twice with hot water into same flask.

Place a strip of platinum foil in the flask, in contract with a piece of C. P. amalgamated zinc, and allow to stand about an hour. Empty the flask into a 250 c. c. beaker, and wash out flash with cold water into the beaker. Titrate with a solution K. Mn. O_4, each c. c. of which equals one milligramme Fe. Calculate to $Fe_2\ O_3$. Suotract weight of $Fe_2\ O_3$ from weight of $Al_2\ O_3 + Fe_2\ O_3$; to get weight of $Al_2\ O_3$, it is well to reduce an equal volume of water and $H_2\ SO_4$, and titrate also, and apply as a correction to volume of $K\ Mn\ O_4$ used.

Combine the filtrates from the above precipitations, make strongly alkaline with $N\ H_4\ OH$. Boil, and while still boiling, add about 15 c. c. of a boiling saturated solution of ammonium oxalate, continue boiling and stir for a few minutes, allow to settle.

The precipitated calcium oxalate will come down in a granular state, and filter easily, without running through the filter paper.

Filter and wash with hot water.

Remove the beaker containing the filtrate, and place a 500 c. c. flask beneath the funnel. Make a hole in the filter paper, and wash the calcium oxalate into a flask. Place the filter paper into a flask, and add about 200 c. c. hot $H_2\ O$. Care-

fully add 10 c. c. concentrated $H_2 SO_4$, shaking flask at each addition of the acid.

Titrate with a solution of $K Mn O_4$, one c. c. of which is equivalent to .028 gms. Ca O.

Evaporate filtrate from calcium oxalate preciptation to about 150 c. c., adding a little $H N O_3$ to get rid of $N H_4 Cl$. Allow to cool, add about 10 c. c. of a saturated solution of sodium phosphate, make strongly alkaline with $N H_4 O H$. Stir well, and allow to stand over night.

Filter and wash with dilute $N H_4 O H$. (1 in 10), dry in an air bath, and ignite in a porcelain crucible. Allow to cool. Add a drop of strong $H N O_3$, ignite again until white, cool and weigh as $Mg_2 P_2 O_7$. Calculate to Mg O.

Determination of $K_2 O$ and $Na_2 O$.

Weigh 1 gram of the glass powder into a 100 c. c. platinum dish. Add enough water to cover the powder, and cautiously add H F drop by drop, until effervescence ceases, and the powder is dissolved. Add about one half a c. c. of concentrated $H_2 SO_4$, and evaporate on a sand bath until dry. Heat over a bunsen burner to drive off free $H_2 SO_4$, and bring to a dull red heat.

Dissolve in dilute H Cl (1 in 2), add a drop of $H N O_3$, boil, and when boiling add about 10 c. c. $Ba Cl_2$, filter and wash with hot water. This will remove the SO_3 from the solution, leaving the alkalies present as chlorides.

Make filtrate alkaline with $N. H_4 OH$, and add about 10 c. c. $(N H_4)_2CO_3$. Filter and wash with hot water. This precipitation removes the Al, Fe, Ba, Ca, and part of the Mg.

Evaporate filtrate to dryness in a platinum dish, and ignite to drive off all $N H_4 Cl$.

Redissolve in $H_2 O$, and add about 5 c. c. $(N H_4)_2 CO_3$. Filter and wash with hot water.

This precipitation removes the remainder of the Mg, and leaves only the alkalies present as chlorides. Evaporate the

filtrate to dryness in a weighed platinum dish, ignite gently, cool and weigh, the difference is K Cl + Na Cl.

Redissolve in water, and add about 5 c. c. of solution of $H_2P + Cl_6$, evaporate in a porcelain dish on a water bath until nearly dry. Remove from water bath and allow to dry spontaneously. Redissolve in dilute alcohol (1 to 1) and filter through counterbalanced papers or Gooch crucible. Wash with dilute alcohol (1 to 1) until the washings are colorless, dry at 100° C, cool and weigh as $K_2P + Cl_6$. Calculate to K_2O and K Cl. Subtract weight of K Cl from weight of K Cl + Na Cl found above, and calculate Na Cl to Na_2O.

DISCUSSION.

MR. LINTON—It is to be regretted that Mr. Uhlig has not gone further in his paper. His directions cover the analysis of only the simplest varieties of glass—alkali-lime varieties, following the general methods in use for all silicate analysis. Other varieties, for instance those which contain boron, fluorine, or phosphates along with the silicates, present more difficulty. Accurate methods for the analysis of such would be of considerable value.

MR. KEMERY—Is not lead of very frequent occurrence in glass?

MR. LINTON—Yes, it is one of the principal bases of all fine flint and optical glass. Barium and zinc are also used to a considerable extent. There is of course no particular difficulty in determining these. I was at one time anxious to get a good method for the determination of boron, which occurred in considerable quantity in a sample of jena glass I was analyzing. I looked up a number of methods and selected three that I thought would be most suitable. The ones I tried were: (1) That of F. A. Gooch, in which boric acid is distilled with methyl alcohol as methyl borate and then added to a previously weighed quantity of Ca O, and heated to constant weight, the increase in weight giving the B_2O_3. (2) The method of E. F.

Smith, in which the boric acid is precipitated by sulphate of manganese, in presence of excess of alcohol, as manganese borate. The quantity of manganese sulphate used being known, and the excess titrated with potassium iodide and thiosulphuric acid, the amount of manganese borate can be determined and the $B_2 O_3$ calculated. (3) The method of Morse and Burton, in which the borate solution is absorbed by anhydrous copper sulphate, the boric acid extracted by alcohol and added to a known quantity of barium hydrate in solution. The excess of barium hydrate is precipitated by carbonic acid, the mixture of barium carbonate and borate dried and heated to constant weight. From the difference between the weight found and the weight of all the barium as carbonate, the $B_2 O_3$ can be calculated. I had no success in getting accurate results with any of these methods, the last one being, however, the most satisfactory of the three.

Mr. Walters—I thing the boron could be determined as boro-fluoride of calcium.

Mr. Linton—Mr. W. E. Garrigues once proposed to fuse the borate glass with $Na_2 Co_3$, dissolve in water and divide the solution. In the one portion determine total alkali and silica. Dry and weigh the other portion after ignition, then dissolve and determine Co_2. The weight of the second portion less $Na_2 O$, Co_2 and $Si O_2$ gives the $B_2 O_3$.

Prof. Phillips—What method do you use in determining arsenic in glass?

Mr. Linton—I have always used the method of precipitation with $H_2 S$, dissolving in ammonia, precipitation with magnesia mixture, weighing the precipitate after ignition as $Mg_2 As_2 O_7$.

Mr. Kemery—How is fluorine determined in glass where it is present?

Mr. Linton—Like the boron determination, I have never found a satisfactory method, although I have never gone into the matter very thoroughly. It seems to me quite possible

that in the fusion of such glass, tetra-fluoride of silicon could be formed and volatized, which would render the results inaccurate.

On motion, the Section adjourned at 10 P. M.

CHAS. H. RICH, Sec'y.

ALFRED E. HUNT,

TENTH PRESIDENT OF THE SOCIETY, 1892.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

The two hundred and twenty-fifth regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the lecture room of the Society's house, 410 Penn. Ave., Pittsburg, Pa., Tuesday evening, May 20, 1902, at 8 o'clock, with the President, Mr. Charles F. Scott, in the chair, and ninety-three members and visitors present.

The minutes of the preceeding meeting were read and approved.

The Board of Direction reported the names of ten applicants for membership that had been approved, and would be voted on at the next regular meeting.

The following persons were then balloted for and duly elected to membership.

NAME	OCCUPATION AND ADDRESS.	ENDORSED BY
CHARLES F. ALBRECHT,	Superintendent Painter Mills, American Steel Hoop Co., Pittsburgh, Pa. h. 525 Avery Street, Pittsburg, Pa.	Richard Hirsch, Charles W. Ridinger.
THOMAS J. BRAY, JR.,	Chief Engineer of United Engineering & Foundry Co., Fifty-fourth street and A. V. R. R., Pittsburg, Pa.	Richard Hirsch, G. W. Knotts.
ELLIAS CHESROWN,	Salesman for Westinghouse Electric & Manufacturing Co. East Pittsburg, Pa., h., 249 South St. Clair Street, Pittsburgh, Pa.	Charles F. Scott, Percy H. Thomas.
GEORGE G. CRAWFORD,	Manager National Department, National Tube Co., McKeesport, Pa.	Wm. A. Cornelius, W. H. Coster.
ALEX WILSON CROUCH,	Manager Dearborn Drug & Chemical Works, 726 Park Building, Pittsburgh, Pa.	John W. Landis, N. C. Wilson.
EDWARD J. DITTMAR,	Assistant Superintendent American Steel Hoop Co., Painter Mills, Pittsburgh, Pa., h., Crafton, Pa.	Richard Hirsch, Charles W. Ridinger.

Mr. Albree—Under the item of new business I suppose the Charter and new By-Laws will come up. The Charter and By-Laws which we have prepared are the result of a great deal of work by the original committee, and latter of the present Board of Directors. The old and the new committees are in perfect accord on the various sections and items and we present this new list of By-Laws for the adoption of the Society, with the decided recommendation that it be passed in its present form by the members, and in behalf of those who are concerned in working over the By-Laws, I move that the By-Laws as set forth in the little pamphlet I have here, be accepted and hereafter be the By-Laws of this Society. The Charter, of course we cannot change, it being fixed.

Mr. Engstrom—We have with us now quite a number of new members who, by reason of their having joined our Society recently, are not entirely familiar with the work that has been done in this matter, and I think therefore, a short review of the history of the case is due them, and with your permission I will make it as short as possible.

Some time ago, the Board of Direction came to the conclusion that our Society should have a new constitution. A committee was appointed to consider matters. This committee spent a great deal of work and thought upon it, and sent in a draft which was ordered printed and taken up for discussion. The discussion was taken up in this manner: They started from the beginning, taking up paragraph by paragraph, and section by section, discussing thoroughly and changing each where they thought it could be improved. Each section was passed conditionally upon a final vote on the whole thing, when we finished it. This was in the spring of the year, and that discussion occupied our time for several evenings at both the regular meetings and the special meetings held for that purpose. Time rolled on until summer came with its scorching heat and as a matter of necessity the number of members

at the meeting thinned out more and more until I remember very vividly the last meeting we had very few who mustered up the courage to stay. That evening it was 11.00 o'clock when we got through with the last section. In the beginning of the discussion some of the machines run under high pressure and by the time we got through with the discussion there was not enough energy left to tackle that final vote. The meeting was adjourned and was left there for I don't know how many years; and the thing to be done now is to pass that final vote. In view of the time and labor spent upon it, I sincerely hope the Society will be in favor of its adoption. As I mentioned before, quite a number of corrections were made in our discussion and I now understand that they had spent a great deal of time entirely reviewing the whole matter and I am entirely satisfied that it is now in good shape and would recommend it and cast my vote for its adoption.

Dr. Stahl—I think there are a few points that are open to discussion in regard to the motion. According to Art. 11, Sec. 11, all members outside of Allegheny County will not have to pay dues. I will read Sec. 11. "The dues of active members residing in Allegheny County, Pa., shall be $7.00 per annum up to January 1st, 1903, and the annual dues thereafter shall be $8.00." On page 17 there is an error in the language used. It says "except that they shall be "appointed" by members of the sections. It should be "elected". It also says Section 6 instead of Section 5."

Mr. Albree—I change my motion to read that the By-Laws be passed subject to additions and corrections as indicated by Dr. Stahl.

President—The motion is in reference to passage of By-Laws with additions and corrections indicated by Dr. Stahl, namely, that the dues of the members outside of Allegheny County Pa., shall be $5.00 per year and that on page 17 the word "appointed" be changed to "elected," also the words Sec. 6, be changed to Sec. 5. Carried.

The subject for this evening is "High Office Buildings." One of the points in which the engineer has most vitally touched the affairs of our modern city life has been in the high office buildings. While the engineering work in one way, in the way of the rapid transit facilities for quickly getting from one place to another, has been taking the attention of the engineers, and vast strides have been made in the means of transportation from place to place, on the other hand, there has been this tendency toward concentration and the locating of more and more on the small area of ground in the interior part of the city. I saw a short time ago a very interesting statement with regard to the Equitable Building, the home office of the Equitable Life Assurance Society in New York City. It stated that when that great building was projected thirty years ago, it was proposed to be the greatest building of its kind in the world; that the new methods of construction and radical ideas were to be involved in the new building and that when the President of the Society proposed four passenger elevators, it was thought to be something so fanciful that the idea was laughed at. They finally compromized on one passenger elevator. That was within the life-time of all of us. To-day more people are carried vertically in New York City than are caried horrizontally. And although the diferent car lines are taxed to their capacity, more persons are carried in elevators than in surface cars. The high office building is not a simple thing. It is one in which the engineer has had to gather together many things, and really, the secret of it all is the steel which makes possible the frame work of these buildings; and together with that has come all sorts of new things, such as fire-proofing, elevators, the power plants, the steam plants, the vast list of internal things for heating, lighting, ventilation, and various systems of piping, wiring, etc., throughout the building, the plans and drawings showing the work for all these different things, making a wonderful system. In itself, the telephone exchange facilities are equivalent to those of a small

town or city. All these things which the engineer has done are conspiring to change business life and the whole method of doing business by which the centers of cities are densely populated. Several times the amount of business can be done in the same area. One of the most striking illustrations of progress of the past ten years is to take the contour of New York City as it is seen from the Jersey City side. Most of us remember the time, only ten or fifteen years ago, when the World Building was a miraculous thing, standing out against the horizon. Now the World Building is lower than many other buidings. Trinity Spire is obscured by high office buildings and is below the windows of some of the neighboring buildings. All this, I say, is one of the things which has come about through the modern engineer. It is to make a study of the features of engineering for which we are called together here this evening. As there are a number of papers, some of which are printed, the readers of the papers propose to present those parts of the papers which are most interesting for discussion and will leave out those parts which are of value in the proceedings, such as statistics, etc., but do not assist much in the discussion.

As I must be under the necessity of leaving the city by train, and as Prof. Phillips, the first Vice-President, has an engagement which will prevent his being here all the evening, I will ask Mr. Albree, the second Vice-President, to take the chair.

MR. ALBREE—Gentlemen, not to lose any further time, the first paper on the list is "Steel Framework for High Buildings," by Mr. Chas. Worthington.

CHARLES E. DOWNTON, { Charles F. Scott, N. W. Storer.

With Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. h., 5 Campbell street, Wilkinsburg, Pa.

JAMES McA. DUNCAN, { Charles F. Scott, E. S. McClelland.

In charge of Direct Current Correspondence Department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., h., 1125 Walnut St., Wilkinsburg, Pa.

GEORGE B. DUSINBERRE, { Charles F. Scott, P. H. Thomas.

Manager Department A., Westinghouse Electric & Manufacturing Co. East Pittsburgh, Pa.

SAMUEL B. DUSINBERRE, { Wm. A. Bole. E. S. McClelland.

Purchasing Agent, Westinghouse Machine Co., East Pittsburgh, Pa., h., 712 Lamar avenue, Wilkinsburg, Pa.

HARRY C. EBERT, { Charles F. Scott, H. P. Davis.

Assistant to Fourth Vice President, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., h., 226 North Craig street, Pittsburgh, Pa.

FREDERIC A. ENSIGN, { Charles W. Ridinger, A. G. Wilkins.

Newspaper Advertising, Bellevue, Pa.

RUSSEL S. FEICHT, { Charles F. Scott, Percy H. Thomas.

Designer in Engineering Department, Westinghouse Electric & Manufacturing Co. East Pittsburgh, Pa., h., 431 Shady avenue, Pittsburgh, Pa.

FRANK L. FUGATE, { Richard Hirsch, H. Ely Myers.

Mechanical Draftsman with H. K. Porter Co., Forty-ninth street and A. V. R. R., Pittsburgh, Pa., h., 257 Fisk street, Pittsburgh, Pa.

EDWARD D. HANCOCK, { Milnor P. Clark, Victor Beutner.

Draftsman for Julian Kennedy, Pittsburgh, Pa., h., 340 South Highland avenue, Pittsburgh, Pa.

HARRY S. HARROP, { F. Z. Schellenberg, Samuel A. Taylor.

Engaged in Civil Engineering, 316 West street, Wilkinsburg, Pa.

HALBERT K. HITCHCOCK, { Charles F. Scott, Chester B. Albree.

Experimental Work on Electric Furnaces, Creighton, Pa., Walton, Pa.

NEWTON L. HOPKINS, { F. Z. Schellenberg, Samuel A. Taylor.

With S. A. Taylor, General Engineering, 82 Schmidt Bldg., Pittsburgh, Pa.

LOUIS S. KINNAIRD, { D. Hunter, Jr., Charles W. Ridinger.

Assistant M. M. Pennsylvania Co., Allegheny, Pa., h., 841 Hemlock St., Avalon, Pa.

HENRY L. LONGWELL, { Charles F. Scott, N. W. Storer.

Mechanical Engineer, Westinghouse Machine Co., East Pittsburg, Pa., h., [illegible] avenue, Pittsburgh, Pa.

ANDREW E. MACCOUN, — Charles F. Scott, N. W. Storer.

Superintendent of Electrical Department Carnegie Steel Co., Braddock, Pa.

RALPH M. MORGANSTERN, — R. A. L. Snyder, Geo. K. Smith.

Subway Engineer of The Central District & Printing Telegraph Co., Pittsburgh, Pa., h., 1305 Fayette street, Allegheny, Pa.

GEORGE C. MORS, — F. L. O. Wadsworth, John A. Brashear.

Assistant Chief Engineer of American Tin Plate Co., Pittsburgh, Pa., h., 1 Clayton avenue, Allegheny, Pa.

DANIEL A MONROE, — A. J. Holmes, E. S. McClelland.

Superintendent Pittsburgh Meter Co., Pittsburgh, Pa., h., 400 Whitney avenue, Wilkinsburg, Pa.

MARK W. McGAFFEY, — S. M. Kintner, Russell E. Waggoner.

With C. West & Co., Carriage Manufacturing, 420 Duquesne Way, Pittsburgh, Pa.

PERCY NICHOLLS, — Charles F. Scott.

Engineer in Mechanical Engineering Department Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

EUGENE W. PARGNY, — Sumner B. Ely, H. H. Anderson.

Manager American Sheet Steel Co., P. O. Box 1427, Pittsburgh, Pa.

ALBERT R. RAYMER, — J. A. Atwood, Emil Swensson.

Assistant Chief Engineer Pittsburgh & Lake Erie R. R., Pittsburgh, Pa.

H. B. ROBINSON, — Charles F. Scott, George E. Klingelhofer

Superintendent Pittsburg Valve Foundry Construction Co., Fifth & Duquesne Way, Pittsburgh, Pa.

THEODORE H. SCHOEPF, — Charles F. Scott, N. W. Storer.

Engineering Department Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., h., 724 Whitney avenue, Wilkinsburg, Pa.

ZENAS H. SIKES, — Richard Hirsch, L. W. Hildner.

Draftsman in Structural Department Riter-Conley Manufacturing Co., Pittsburgh, Pa., h., Crafton, Pa.

JOHN H. SMITH, — Charles F. Scott, T. S. Perkins.

Westinghouse Companies, Publishing Department, Pittsburgh, Pa., h., Wyoming street, Pittsburgh, Pa.

THEODORE VARNEY, — Thomas S. Perkins, Charles F. Scott.

Engineer in Detail Engineering Department Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., h., 5719 Howe street, Pittsburgh, Pa.

THOMAS WOOD, — Samuel A. Benner, Emil Swensson.

Assistant General Agent Carnegie Steel Co., Carnegie Building, Pittsburgh, Pa

STEEL FRAMEWORK FOR HIGH BUILDINGS.

BY MR. CHARLES WORTHINGTON.

The high buildings, commonly known as "sky-scrapers," are made possible only by the use of a metal framework, which supports all or most of the loads and transforms the walls into mere shells to protect the occupants from the weather and to give a suitable outward appearance to the building.

While the engineering problem in the design of one of these structures is very important, it is altogether subject to the will and whim of the architect in its solution, and in the completed building the engineer's work is altogether hidden from view.

Types: For buildings up to six or eight stories in height the walls may be self-supporting from the foundations up, while the steel work supports all floor loads, and for such buildings this is common construction. For higher buildings, however, the steel frame is usually made to carry all floor loads and walls as well, in which case girders are provided at each floor level to support the walls of the story above, or sometimes several stories at once are carried on one girder.

Loads: The loads for which the framework of such structures must be designed are as follows:

(a) The Dead Load, consisting of the weight of all permanent construction. For purposes of calculation this may be conveniently divided into the floor load, wall load and weight of columns. The floor load includes weight of all floor construction, beams and girders, and is calculated at the outset when style of floor is determined upon; for 12-inch I-beams, spaced about 5 feet apart and ordinary flat hollow tile arches, this weight will vary from 85 to 90 pounds per square foot. For the roof a similar construction is generally used and weighs somewhat less. The weight of walls is calculated on the basis of brickwork weighing 115 pounds, and sandstone,

granite, marble, etc., 170 pounds per cubic foot. The weight of steel in columns may be approximated at first, and after designing the column section the true weight substituted.

(b) The Live Load, which is an assumed loading intended to include all loads not forming part of the structure itself.

The live loads required by the building laws of Greater New York, per square foot of floor area, are as follows:

For floor beams and girders:

Dwellings, apartment or tenement houses, hotels and lodging houses, 60 pounds.

Offices, 150 pounds for first floor and 75 pounds for floors above the first.

Schools, 75 pounds.

Stables and carriage houses, 75 pounds.

Halls for public assembly, 90 pounds.

Ordinary stores, buildings for light manufacturing and light storage purposes, 120 pounds.

Stores where heavy materials are kept or stored, warehouses, factories, etc., 150 pounds.

Roofs pitched less than 20 degrees, 50 pounds, measured on horizontal plane; roofs pitched more than 20 degrees, 30 pounds.

Sidewalks, between curb and building line, 300 pounds.

For columns the above loads are used as given where the building is five stories high or less; when more than five stories high the above loads are reduced as follows:

For roof and top floor, full loads.

For each succeeding lower floor, 5 per cent. is deducted until 50 per cent. is reached, when that load is used for all remaining floors.

These live loads represent the practice in New York City, where such construction has been developed further possibly than anywhere else; at the same time they are merely approximations, and not many buildings, excepting theatres and such halls where crowds of people are wont to gather, are ever sub-

jected to their full live loads; especially does this apply to the columns, where the loads accumulate from story to story. On this account, therefore, it should not be attempted to calculate the loads and stresses as exactly as is done for railroad bridges or similar structures.

(c) Wind Loads. In providing against the effect of wind there is great diversity of opinion amongst the architects. One will provide bracing to carry all the wind load by means of the metal framework and another will provide no bracing whatever, assuming that the brick curtain walls will perform this function.

From the engineer's standpoint every such structure should be designed to resist the greatest windstorm that may possibly occur in the locality, especially where the wind has such full sweep as it has against the upper portion of a high building. This possible storm may never occur, but the disastrous results of a collapse from such a cause should be provided against to a certainty. Where the curtain walls are solid, or even where windows break their continuity, the brick work can be assumed to resist with safety considerable of the tendency to distort under live load. But, with a view to greater safety and rigidity, the writer would suggest that in all cases the metal frame be subjected to a wind load of from 10 to 20 pounds per square foot of exposed surface of walls, depending on local conditions and the relative continuity of the curtain walls, and that this load be transferred to the foundations through the framework alone. It will not ordinarilly be necessary to increase the area of column sections on this account, as the maximum live load and maximum wind load would not be likely to occur together; the girders between the columns, considered as portals, receive their maximum flange stress at the ends, reducing to zero at the center, while, considered as beams for dead and live loads, the maximum flange stress occurs at the center, reducing to zero at the ends. If, therefore, the girders along the outer walls and possibly at one

or more well-chosen partitions, if the building is wide, be made sufficiently deep and properly connected to the columns to make them efficient as portals, and the metal making up the column sections be so distributed as to offer a maximum resistance to bending in the direction of greatest wind pressure, the above amount of wind can be provided for with only a slight increase in the amount of material required.

Designing: In making the design for the metal framework of a building, the engineer is provided with the architect's floor plans and external elevations, made to scale. The location of the columns is usually fixed by the architect at the outset; for economical construction these should be spaced from 16 to 20 feet apart, say 16 feet one way and 20 feet the other. After determining upon the most suitable location for the wind portals, the floor plans of beams and girders are first made; this is best accomplished by laying out the beams to scale on prints of the architect's floor plans, spacing them the proper distance apart and arranging the framing around elevator shafts, stair wells, etc. The proper spacing of beams depends, of course, on the assumed loading and should be determined for the average span in deciding upon the depth of beam; for office floors the ordinary spacing of 12-inch I's is about 5 feet. In spacing the beams, those occuring most often should be the minimum section rolled, as this is the most economical of material. The girders which support the floor beams, and which are in turn supported by the columns, should be as deep as possible for economy and for stiffening against wind; in many cases the clearance below requires the girders to be of same depth as the beams attaching to it, then two beams, fastened together by cast iron separators every 4 or 5 feet, are used, but such girders are of little value in resisting the wind. The tops of all beams and girders, excepting those along the outer walls, must be flush with each other in order to clear the floor. Care should be taken that at each floor all columns be held in place in not less than two directions by the end of a

The bending moment in the column will be greatest at these same points of connection and of value

$$\frac{1}{4} W \left(\frac{h\text{-}d}{2} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The column section should be proportioned with a view to best resisting this bending, but as stated above, the actual area need not ordinarily be increased over that required for dead and live loads.

In Fig. 4a is shown in detail the typical form of portal connection to column, as designed to resist the stresses indicated in Fig. 4.

Column Splices:—The columns are usually built in two-story lengths, faced square at the ends and connected by splice plates on all sides: these plates increase the continuity of the column at the joint, but the large axial load on these columns would generally be sufficient in itself to make the joint continuous for the ordinary bending to which they are subjected. This is shown in Fig. 5; a horizontal force H on the column would tend to open the joint and thus shift the point of application of the axial load P towards the leeward corner of its bearing, as shown; this would cause a reverse moment of value P d. This reverse moment is usually very great, owing to the proportionately large values of P, especially in the lower stories.

Foundations:—The ordinary practice in designing of foundations for steel frame buildings calls for a pedestal supporting each colunn. These pedestals should be separate and isolated if possible, with the center of load applied at the center of pedestal, or, if it becomes necessay to consolidate two or more pedestals, care should be taken to have the center of gravity of this group of loads coincide with the center of pedestal base. Care should also be taken to have the pressure on earth foundations uniform under all pedestals, dead load only considered, in order that there may be equal settlement throughout the building.

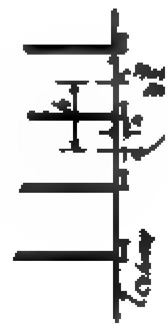

Fig. 1.

Fig. 2.

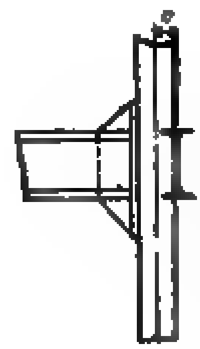

Fig. 2a.

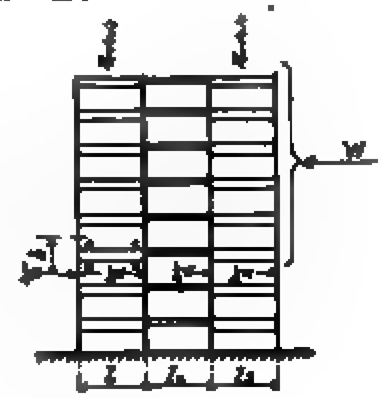

Fig. 3.

Fig. 4

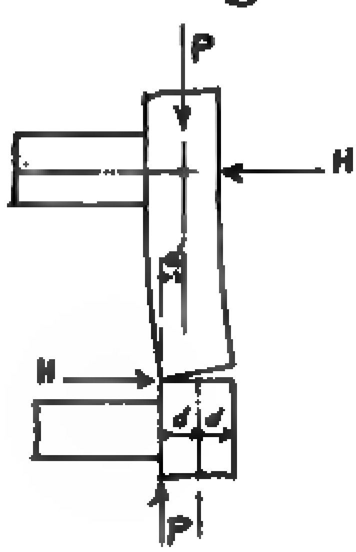

Fig. 5.

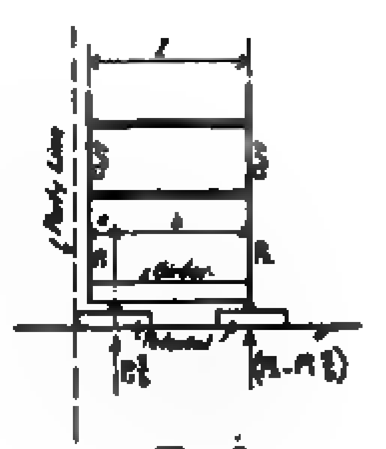

Fig. 6.

The laws of Pittsburgh require owners of abutting property to agree upon a party wall; this simplifies construction considerably, for, in places whe rethere is no such law, it becomes necessary to locate the pedestals supporting all outer columns well within the limits of the building in order to permit of spreading the base to reduce the presure on foundations. This is usually done by means of the cantilever arrangement shown in Fig. 6.

The pedestals themselves are generally made of two tiers of grillage beams, one above the other, and at right angles to each other. The column base resting directly on the upper tier of beams, or, where the footing is very large, on a special steel casting, which in turn rests upon the upper tier of beams.

Under the lower tier of beams there is a layer of concrete; this should not be less than 12 or 15 inches thick, and care should be taken to have all foundation beams thoroughly embedded in concrete, to prevent rusting.

Grillage beams should be secured against spreading by tie rods passing through all beams of each tier at intervals in their length.

MR. ALBREE—Gentlemen, we will hear the other papers before the discussion is formally opened. Mr. Worthington has described the technical features of modern steel constructing and building. He alluded in a very general way to the relation between the engineer and the architect. That is a subject that has been discussed before in this Society. We have already learned from him as to the engineering part of the structure as relates to the steel work.

We will now be favored by Mr. C. A. MacClure with a paper on "The Designing of Office Buildings." Mr. MacClure is an architect here in Pittsburg, and it will be a great pleasure to the engineers to hear from the architect's side of the question. It is, you know, a very difficult problem for an architect to make a twenty-story building a thing of beauty and a joy forever. It has been handled in a great many ways by people of our city and in different cities. We will be glad to hear Mr. MacClure tell us about some of the difficulties to be encountered.

THE DESIGNING OF AN OFFICE BUILDING.

(A TWENTY MINUTES' TALK).

COLBERT A. MACCLURE, B. S.,

OF MACCLURE & SPAHR, ARCHITECTS.

An office building, being primarily built for the purpose of an investment, becomes an architectural problem which may be roughly stated as follows:

Given a piece of property; solve for a building on the same which will yield the greatest return upon the investment. (This does not exclude, but necessarily includes, architecural excellence, since other things being equal, such a building is more attractive to tennants, which in turn, enhances the investment.)

The architect's first duty is to obtain data in regard to the size and shape of the lot; the height, thickness and shape of the walls of the adjoining property, and depth of neighbor's cellers; the location and size of sewer which serves the property, the width of the adjoining street, or streets, together with their sidewalks and grades; and to familiarize himself with whatever legal restrictions may be on the property, and the laws governing the erection of such buildings in the locality under consideration. Having thoroughly digested this data, the architect is ready to begin the solution of the problem, which involves everything from the conception of the building as a whole, to the most minute detail. It involves the use of knowledge of thousands of different materials, crafts and people, and the making of scale or full sized drawings of every part of the structure; of the size and location of every piece of brick, stone, wood and metal, and the rivet holes in the last named; of the ornamental modeling and curve of the separate arms of the light fixtures. It involves the employment of temperaments which have a keen sense of proportion, color and an artistic touch; a painstaking taste for details; executive

ability; and a breadth of view which gives every part its proper value in the whole.

Since the element of time figures largely in an investment, it is necessary that office buildings be designed with great dispatch. Under this pressure complete plans and specifications for modern high office buildings, including plumbing, heating, power plant, elevators, refrigerator machinery, electric wiring for lights, clocks and protective system, light fixtures, fittings and decorations, are not infrequently put in the bidders' hands in six weeks time. It is evident upon statagment, that no one person could accomplish such a task. The designer knows this full well. Having obtained the best size and arrangement of offices, corridors, elevators, toilets, etc., and the best light and air, and having determined the treatment of the interior and exterior of the building with reference to the class of tenants for which the building is intended, and the outlay of money, the architect calls in experts in the different professions and trades to take up their respective works. All professionally successful architectural firms are made up of experts in one or several of the branches, and most have experts in several other branches constantly in their employ. The architect of a modern office building is essentially an expert at the head of a number of experts in the professions relating to such buildings. This is a fact so well known among architects that it is a fruitless subject for discussion among them, and yet it is one of the several facts about the profession which, in the experience of the writer, is generally misunderstood by the public, the owner, and even some of the experts employed in the work.

Assuming that the architects and the other experts are properly trained in their respective branches, it is necessary for the best results that they clearly understand the relation of their respective duties. This involves something more than a mere technical excellence; it involves a breath of view and the use of common sense.

The architect knows the principals of construction, the desirability of rectangular spans and uniform length of girders and beams; in short, simplicity of construction. If all buildings could be so designed, a "level headed" assistant in the architect's office, could, with the aid of a hand book and a knowledge of graphic statics, serve as the constructional expert. These cases are, however, the exception. Take, for instance, one case which has occurred in the writer's experience, where an owner wished to build ten stories high on an eleven sided lot facing on two non-parallel streets, and having no two sides parallel and not a right angle in the plot. In addition, the adjoining neighbors refused to allow the owner's footings to project onto their property. The owner wished to rent the basement, and the sea level was about three feet below the proposed basement floor. Furthermore, the building was to be designed to compete with others in the vicinity which had not all of these difficulties of construction. Such a problem needs, for the constructional expert, an engineer who has all the data and technical skill so well at his command that the greater part of the time allotted to him can be used in inventing ingenous ways of overcoming the difficulties imposed upon him.

During the designing of the structure, the engineer would suggest certain encroachments upon the space allotted to his structure. If a compensating reduction in price could be shown, it was usually adopted, and if not, another scheme was promptly invented by him. Such an engineer is an ideal constructional expert, and adds greatly to the pleasure of designing an office building.

Here are photographs (see plates 1 and 2) of the foundation work of a build-ing in New York showing the ingenuity of the structural engineer in overcoming similar conditions to those just described. This fifteen story office building was erected in seven months, and holds the record in the United States for fast building of its class. The constructional engineer was Mr. S. C. Weiskopf, whom, no doubt, many of you

know. Mr. Weiskopf's recent work in this direction is more worthy of study than any that has come to the writer's knowledge. Here also is a print of a truss by the same engineer which is remarkable, not in its design, but in the economy of using this particular form in the place for which it is designed. (Truss not produced here.)

The architect's mechanical plants are as much a source of humorous railery among mechanical engineers as the latter's buildings are among the architects. The question is frequently asked, "Why is it that mechanical plants in office buildings are so often inadequate?" Referring only to those which are put in by competent experts, there are two reasons:—(1st) The space allotted to, or available for, the plants, is inadequate, and (2nd) After the plant is completed, the owner, finding he can sell power to a neighbor, or for various reasons finds it desirable, requires more of the plant than it was designed to perform.

The remedy of No. 1 is to show the owner a definite statement in non-technical language, if he is not a technically trained man, convincing him that it is a saving of money to increase the space. As against your efforts, you have the renting agent, who furnishes a statement of about two lines in length, showing what the space in question can be rented for. The agent has the advantage of brevity, which is by no means negligible when dealing with a busy man. Remembering that an office building is primarily an investment, you will appreciate why it is difficult to get four feet between engines when you admit yourself that two feet would do.

When the space is not adequate, it is a question whether a sub-cellar, at a very considerable increase in cost of the building, shall be added, or whether the space available will answer. Here, again, the consideration of investment sits in judgment.

There seems to be no practicable way of providing for future power when the nature and amount of it is not known. There is, however, no reason why the architect and the me-

chanical expert should not put the question to the owner and get an answer in writing, thus relieving them from possible future blame justly given.

In the eyes of the law the architect bears much the same relation to his clients as the Continental Congress did to the colonists; he can make recommendations but has no authority to force their adoption. The architect does not need such authority, and probably would not use it more than once in a lifetime if he possessed it. It will, however, often bring the architect and mechanical expert into clearer understanding if the true relation between the owner and architect is borne in mind.

SOME MECHANICAL FEATURES OF THE KEYSTONE BUILDING, FOURTH AVENUE, PITTSBURG, PA.

This building differs somewhat from office buildings in its mechanical equipment. It consists of:

1st—2— 60 H.P. low pressure boilers which are used only for heating the building.

2nd—2—125 H. P.
2—175 H. P. } Westinghouse gas engines.

3rd—2— 75 K.W.
2—110 K.W. } Westinghouse generators.

4th—1 Electrically operated water cooling plant.

5th—2 Electrically operated house pumps.

6th—2—1 Electrically operated deep well air lift plant. This is to use the water from artesian wells on the ammonia condensors.

7th—Four electrically driven hydraulic elevators.

The advantage of using gas for fuel at about 12 cents, and with the average rate of consumption of 12 cu. feet per H.P. per hour as compared with coal, is readily apparent.

The heat from a steam plant in the basement of an office building has always been a source of annoyance and discomfort during the summer months, and particularly when the

first floor is given up, as is often the case, to handsomely appointed banking rooms. There is no question but that a gas engine plant gives off much less heat than a steam plant of the same capacity, and this was one reason for their adoption in the building under discussion.

All of the units are not in use at this writing, but the results to date in regard to surplus heat on the first floor give promise that this difficulty is successfully disposed of.

The use of gas engines made the problem of elevators an unusually interesting one, as the following requirements were demanded:

1st. To profit by the economy of the two-power system as compared with the single power system.

2nd. To profit by the cheapness of generating power with gas engines as compared with steam engines.

3rd. To secure that nicety of control in a fifteen story shaft which is peculiar to modern hydraulic, as compared with electric elevators.

Mr. B. S. Harrison, of New York City, designed the plant, which, when completed, will be, so far as the writer is informed, the only system of elevators in the country of its kind. It is the two-power system of hydraulic elevators driven by electric pumps actuated by current developed by generators direct connected to gas engines.

It must not be lost sight of, however, that the cost of a first-class gas engine is considerably greater than that of a steam engine.

MR. ALBREE—We have had our eyes opened in regard to the method and madness of architects that we sometimes kick about. We find they are not always to blame and that they have troubles of their own. Mr. MacClure is not a member of our Society, but kindly consented to give us this paper and we greatly appreciate it. In discussing the high office building, as Mr. MacClure has stated, it is necessary to call in the specialists for the various parts, such as Mr. Harris for the

mechanical equipment of the Keystone Bank Building. One of the things is to make the building fire-proof. The matter of fire-proofing, plans, materials, construction, methods, etc., will be discussed in a paper by Mr. Wight, who is a consulting architect of Chicago, and who has come on specially to read this paper for us. Gentlemen, Mr. Wight.

THE FIRE-PROOFING OF HIGH OFFICE BUILDINGS.

BY PETER B. WIGHT, F. A. I. A., CONSULTING ARCHITECT.

It is one thing to speak of fire-proofing in general: it is another and more satisfactory to speak of the fire-proofing of a special class of buildings. Therefore, much that might be said of the fire-proofing of department stores, warehouses, government, state, county and municipal buildings will be herein omitted.

The plan, location, height, means of interior communication, ventilation, and many other conditions incident to a high office building are subject to the purpose for which it is built: and the main one is its value as an income producing investment. The height to which these buildings have been carried has been the main factor that has placed them in a class by themselves, so far as construction and fire proofing are concerned. It is the immovable factor in the proposition. It has come to stay. Ten stories is the lowest limit of height: the highest limit seems to be indefinite. Buildings of this class have made choice building sites more productive of revenue and consequently more valuable than anyone could possibly have imagined, and having given value to the land on which they are erected, they have caused an increase in proportion in the market value of all the lots intervening between them.

The greatest reason for saying that they have come to stay is that those who have invested in real estate at high figures caused by the possibility of such buildings, will never allow their property to be depreciated by any other kind of buildings, or at least any other that will return a less percentage on the investment. Nothing but a general panic and collapse in prices would produce such a result. This would be a financial disaster such as has never been seen, and capital will resist it to the death.

The only contingency to be feared is the condition of our streets when all the improvements in certain quarters are high office buildings. But that will come gradually, and its results may be anticipated.

The high office buildings have been made a success by the possibilities of construction that have been developed with them. They were first built with brick walls, and the highest reached to sixteen stories with this material for support on the outside, as at Chicago, even with its compressible soil and floating foundations. Skeletons of cast iron columns and rolled iron beams were going up to the same height and at the same time. The whole-steel skeleton came when the introduction of rolled steel superseded rolled iron, and it has continued to be the standard construction for these and many other kinds of buildings ever since.

But the possibility to attain this great height with safety came with the inventions of the fire-proofers; to speak more accurately, the inventors of light hollow tile systems of floor construction. The weight of floors was reduced before the weight of walls. Up to 1881 the average of fillings between I beams of buildings having incombustible floors was 70 lbs., whether with brick arches or with corrugated iron covered with concrete. They were at one stroke reduced to 30 lbs. by the use of flat hollow tile 6 inch arches in the 9 story Montauk Block at Chicago. You all know what that means in computing the strength of foundations, walls and columns. From that time the number of distinctively high office buildings increased rapidly. Other inventions followed, though as a matter of history, the iron rail and concrete foundation (now nicknamed the "floating" foundation) was first used under the same builing. It was one of the accidents of my life that I supplied both.

The steel skeleton having become an accepted fact, heavy walls, both exterior and interior, have been practically abolished. The earliest high office buildings had not only exterior,

but interior walls of brick wherever the conditions of the plan would make their use practicable. In addition they were filled with stacks of heavy brick vaults which were permanent fixtures placed where it was supposed there would be a demand for them. Tenants had to select such quarters as suited them according to the original plan of the building, as changes in plans were very expensive and often impracticable. But when the all-steel skeleton abolished the heavy wall it also abolished the vault, and in abolishing the vault, it warned all concerned that the fire-proof qualities must be of such a high grade that the whole building would be a fire-proof vault. So the fire-proof closet had its birth. This was one stimulus to a greater study of fire-proofing conditions.

The modern office building, so far as it can be seen when completed, is practically built by the fire-proofer. His methods render common bricks, on which the main dependence was formerly placed, quite unnecessary. The first great change after the all-steel skeleton was developed was the substitution of the hollow fire-brick or "hollow tile," as it is called, for the common brick; and this was only possible by the use of refractory clays instead of brick clays. It was carried to such an extent in the erection of the 18 story Fisher Building at Chicago that, in this building, which fronts on three streets, there are no bricks except a few that the contractor for external terra cotta used in filling chinks behind his terra cotta wall. Even the dead wall is all built with terra cotta (meaning thereby that made by the contractor for exterior work) and hollow tiles. This illustrates to what extent the hollow tile (meaning such as is made by the fire-proofer) as well as the manufactured terra cotta, have contributed to the development of the high office building.

I am aware that it is contended by many men of your profession that concrete in combination with metal is a better fire-proof material for constructive purposes than hollow building tile. I agree with you that in some cases it is, and therefore

will not seek to provoke discussion. But the fact remains that the hollow building tile made of refractory clay is the material which has actually developed the high office building as we find it to-day, and I think it will always hold the most important place in such constructions. For while the common brick has been to a great extent supplanted, the wall and the arch have not gone out of use. The wall has only been reduced in thickness and in weight, and the weight of it has been reduced in greater proportion than the thickness. Long walls and high walls unsupported are no longer necessary, but they cover just as many superficial feet in height and breadth as before. The mason with his trowel is just as necessary; and while there are many ingenious methods for constructing subsidiary partitions without hollow tiles, and without the help of the mason, there is still no way known for building the exterior walls or the main interior division walls of a building, with the greatest rapidity in all kinds of weather, and without the use of unnecessary quantities of water, except with previously prepared dry blocks of refactory material. Where an arch of large span is required, whether it be a large door, a dome, or a wide span between deep floor beams there has not yet been anything invented, that is lighter for the work required, dryer, more fireproof, more rapidly constructed, and cheaper than the products of fire-clay, set in good cement. Yet there are substitutes, and they have their value, and for special purposes are desirable.

The special qualities and true value of this material, and the kinds that are most reliable for fire-proofing purposes will be considered when the conditions affecting a truly fire-proof office building are considered.

The main conditions to be considered are (1) the plan, (2) the materials, and (3) the constructive methods.

The plan belongs to the architect, and if he consults his engineer it will be a very simple one. It is safe to say that the best planned office building on a rectangular lot, will be one that is worked out on a system of smaller rectangles into which

the lot is sub-divided, with a column at each intersection. The main thing to do is to ascertain the best proporionate dimensions for these rectangles. If they are all the same, there will be only two dimensions for all the girders and beams in the building. Such an arrangement will result from making several sketch plans upon different sub-divisions into rectangles until the best one is discovered. If this is found to be impracticable the system should be abandoned. But if possible the girders should be in straight lines, and the width of the exterior bays should be controlled by the spacing of interior columns. The general dispositions of the plan being adopted, the next thing to do is to study all the contingencies that would permit fire to attack such a plan from without, or invade it within. Every high office building is by its nature a flue, and the problem has heretofore been how to make it less so. So many have despaired of this, that I am inclined to say that what might be possible in a great warehouse, in which vertical drafts can be avoided, need not be thought of, lest the true value of the building as an investment be destroyed. I would therefore advise that the natural flue conditions of a high office building be improved by planning it so that the natural drafts which carry fire upward will, as far as possible, be directed away from the inhabited rooms, and allowed to escape harmlessly through the top of the building. This can be accomplished by permanent flues built of double air space hollow tiles, running through the offices where they are least likely to interfere with future changes of partitions. These flues can be covered at the top with skylights of thin glass which would break in case of fire, while permanent capped pipes also at the top would serve for ordinary ventilation. The openings from the offices into these shafts should be permanent and close to the ceilings. Such flues would carry fire and smoke through the roof and prevent it from spreading laterally. Large glass covered courts should be avoided, as they tend to arry smoke and fire to upper stories and smother the occupants.

As elevators may become as valuable as stairways for means of escape they should, if possible, be placed not in one stack, but in two, and as far apart as practicable. In large buildings this would be a convenience to tenants in reaching their rooms expeditiously. Every large office building should have two entrances connected by a common hallway, and it is equally important that it should have two stairways from the second story to the top, and as far apart as possible. They should not be in position where a rising current of air can involve both a stairway and a stack of elevators. Theorists have sometimes claimed that stairways and elevators should be individually isolated. Such a disposition would so injure the value of the investment that it should not be considered. Besides, an isolated stairway in case of a panic would be unknown to most of the occupants or visitors to such a building. With two vertical stacks of stairways and two vertical stacks of elevators, all connecting with corridors, it would be practicable to place spring doors across the corridors, which would isolate each stairway and each stack of elevators. Such cut-offs in the corridors should be entirely made of light metal frames and polished wired glass. This latter material will also be considered later on in connection with "Materials of Construction." But as part of the plan of the roof it should take an important place. There are many instances in which the study of the natural action of fire in the top of a building shows that it is desirable to use glass that will break as soon as attacked by fire, so as to let the flames and smoke escape. The indiscriminate use of wired glass, therefore, because it will admit light and still resist a current of fire, is not to be encouraged, and it is easy to see that it might be the cause of many deaths from the accumulation of smoke which cannot escape. It is much more important that skylights should be of breakable glass, and to prevent injury caused by its fall they should have wire nets suspended beneath them. There should be such skylights over every elevator and every stairway. And if skylights are not required over them,

as in the case of their being next to outer walls with windows, they should have large ventilators running through the roofs.

Any suggestions as to the capacity of elevators, stairways, corridors and doors seems hardly necessary here, for they are the important considerations which enter into the planning of every building, and are equally, if not more important in a high office building than any other. The objects of a properly built high office building other than the interest of the owner as an investment are safety to human lives, and safety to the property contained in the building, as well as the building itself, as against fire.

This brings us to the second consideration—materials. That such a building must consist of fire-proof materials reinforced with the commonly accepted steel frame has been said. For the exterior, terra-cotta and brick take first place. But these are not necessarily backed with brick. Where they are not, the only material that has been used successfully is hollow fire clay tile. It is now customary in the best buildings to construct the floors and protect the columns and girders before the exterior is covered. The exterior walls are not sufficient to protect the exposed columns and beams at the outer line of the structure. They are only a mask and may fall away exposing the structure. These columns and girders should be first protected exactly as are those of the interior. Various methods are in use. By some it is advocated that they should be encased in Portland cement concrete, completely buried in it, but it is not suggested that any fastening is required other than the adhesion of the cement to the steel, and its own monolithic character. This method denies the necessity for any non-conducting air spaces. I know of only one building in which this was ever done; it was owned by a fire insurance company in New York, and it was done twenty years ago. The columns, which were of the Phœnix pattern, were covered with Portland Cement run from a cornice mold, and showing a moulded finish all around. By others it is proposed

to plaster the columns with cement on a lathing of wire or other perforated metal. And where one process like this is not considered sufficient it is proposed to repeat it twice, and even thrice. This is frequently done, and its chief merit is its cheapness. The common method is to build hollow tile blocks around the columns like a wall, and in some cases two courses of these are used. In severe fires which have occurred in several buildings it has been demonstrated that the exterior layers of these crack, for the reason that the exterior expands, while the interior is cool. The worse defect in the use of hollow tile around columns is that no provision is made for longitudinal expansion. They are built from the girder of one story to the girder next above. As a result it was demonstrated in the last fire that occured in the Horne Department Store at Pittsburg that before the steel columns had absorbed enough heat to cause expansion the hollow tile coverings were so badly *crimped* by expansion against the unyielding girders that many of them fell off. In an earlier fire in the Horne Office Building at Pittsburg, in 1897, the column coverings, which were of thick slabs of semi-porous terra cotta, built as a wall around them, were uninjured. My earliest practice was to use solid blocks of a very high grade of porous terra cotta, both for columns and girders. For column coverings I always secured them to the iron with tap screws. For girders, I made the blocks to fit the sections of I beams, and found that no fastenings were needed, for the form of the I beam is such as hold the blocks tight between the flanges when well bedded in cement. Cast iron columns covered with porous terra cotta, 2½ inches thick, fastened to the iron with tap screws, were tested in a fire in the Grannis Block at Chicago in 1885, where they were pulled out of the ruins with all the fire-proofing attached. There was nothing fire-proof in that building except the columns. I am now satisfied from experience of all the known materials in actual fires that the softness of porous terra cotta is almost as objectionable as the brittleness of hard

burned thin bodied tiles, and that the best fire-proof material is the medium between them, and that is semi-porous hollow tiles with walls at least $\frac{3}{4}$ of an inch thick. The best illustration of their efficiency was seen in the Horne Office Building at Pittsburg, in 1897, the material having been made in your own city, Pittsburg.

Whenever a contract is let for the fire-proofing of a building with clay products, the lowest bidder who secures the contract executes it with the kind of material he can make to the best advantage—it is the product of the clay he happens to mine. It may be suitable for the high grade porous material, or only for hard burned tile. But the best material to produce the results above suggested can only be made by mixing clays—in their natural state they are not suitable. This should be a subject for investigation and study by every manufacturer, so that a reasonably uniform standard article can be produced. It was the good fortune of the Pittsburg Terra Cotta Lumber Company, which made the material that went into the Horne Office Building, to produce a tile with their own natural clay which filled every requirement for a fire-proof material; and which had the necessary toughness and refractory powers to resist extreme heat. Other clays may resist heat, but lack toughness; they become brittle and are not fit for hollow tiles with thin walls. Others again can be burned with large quantities of sawdust, and are wonderful non-conductors, but are too soft and not suitable for resisting severe strains. My own observation has shown that in most localities shales may be obtained, which, when ground and burned with low grade fire clays produce the best material for semi-porous terra cotta.

Too little attention has heretofore been given to standard qualities in burned clay fire-proofing. When a standard is established, recognized and insisted upon by architects, there will be some hope for uniformity in results. As it is, there may be several kinds of burned clay fire-proofing used in one city, and I know of some buildings in which the clay used was

not above the grade required for ordinary flower pots. Where used, however, it was the result of indiscriminate competition aud want of investigation. As a matter of fact most of the buildings fire-proofed with burned clay contain the highest grade of material. But the world will never see this fact demonstrated by the ravages of fire. It has never given the fire-proof office buildings that have been erected within the last fifteen years the credit that is due them, and it never will. It only hears of the occasional one that shows failure in a crucial test. Those that have resisted the elements are dismissed with a paragraph. An occasional failure is not a demonstration that others may be expected. When it betrays the fault or the weakness it should be an object lesson that is profitable. I regret, however, that this is not always the case. I wish the men of my own profession would take as much interest in scientific investigation as you do.

The value of wired glass has been referred to. In an office building it will prove to have its greatest value when used in vertical positions where glass is necessary. It should be used in all external windows wherever possible. But it should always be set in metallic sashes and frames. The supposed necessity for using wood in partitions, for door and window frames, has led to many demonstrations of the fact that this use has helped to destroy the efficiency of the fire-proof materials of which they have been constructed. Experience has also shown that wood should be practically abolished from the interior finish of office buildings, and this can be done now without raising any objections on the part of the tenants. Recent inventions have supplied all that is wanted. There is no longer any necessity for wooden floors. Notwithstanding it has been claimed that they will not burn, they *do* burn, and the oil and varnish which saturate the modern hard wood floors carry fire with great rapidity. The tenants have already anticipated the change, for they have abolished carpets and substituted rugs. If marble and tile are too expensive for floors cement can be

used. A very valuable substitute for cement finish has recently been invented called "monolith." Doors need no longer be made of varnished wood, but of common wood covered with sheet brass and hung to metallic frames, built in fireproof partitions.

Referring now to the third division of my subject—constructive methods—I feel compelled to tread my path with caution, for I may be invading the domain of the C. E. All discussion of constructive methods in fire-proofing seems to lead to the building of floors, and this is where the C. E. has crossed the path of the architect more than once. The fact that extraordinary strength has been developed in constructions in which various combinations of Portland cement, sand and steel have entered, have made them very attractive to gentlemen of your profession. I admit the strength and the ability to prevent fire from passing from one story to another within a given time, and to one who seeks only for these results they are satisfactory. But house building has many ramifications. The conditions under which houses are built are various. Among the most important of these are *time* and *climate*. Another one is permanence. The oldest of the indestructible manufactured materials known to exist on the face of the earth is burned clay. Time may show that the high grades of cement made at the present day come next to it, but we cannot wait for the outcome. Finely divided steel with which it is combined is a very delicate material, and scientists all over the world are discussing the question "what is the best material to paint steel with?"—even where it is used in heavy members of construction. At such a time you will see if you look at nearly all of the high office buildings that have been erected and are now being erected, that the architects who have to do with those buildings pin their faith to burned clay. They have no time to wait and see whether the cement will eat the steel or preserve it, but they know that they have a good thing in clay, and as long as it is the only material which makes possible the building of

furnaces in which iron can be made into steel, they will continue to build it up around the steel skeleton; and I hope it will preserve the steel skeleton for all time. For as the steel must be protected from fire and every inch of it covered, it is certain that when protected from one element it will be found to be pretty well clothed against the storms that try to beat against it and the insidious dampness that steam heat expels. However, I suppose that the discussion about corrosion will last until we have steam heated bridges, and about electrolysis as long as we have damp cellars.

I have said that the architect will always be a believer in *the brick* and its substitutes, and his affection will always cling to his brother, the mason, even though houses may be built without heavy walls. With these materials and his skillful assistants he does not fear that terrible enemy to cement, Jack Frost, and he can get his work done fast enough to suit his client, which is saying a great deal. These are the convincing arguments for the use of burned clay. My only plea is that this most important and universal material may be in the future the object of greater study for the purpose held in view in this paper; that as much investigation and experimentation will be devoted to the determination of the proper methods for manufacturing of clay products into fire-proofing material as has been given to the adaptation of clay for use in the manufacture of steel. Its indestructability is admitted; but it has a different office to perform in the burning building from what it has in the open hearth furnace. It can be made, for it has been made, to withstand water as well as fire. By proper mechanical means it can be made to keep its place under all conditions. It has also a field in constructive work such as has been developed by no other material, in the building of domes, such as those erected by Guastavino. Whatever apparent failures there may have been in this as a fire-proofing material are exceptions to the general practice that has been followed in its use, and only serve as a warning against its unscientific and unpractical application.

Mr. Albree—Gentlemen, we have just heard a paper dealing not only with hollow tile, very ably presenting its merits, but we have had a paper of very great general interest with regard to design of building and with regard to general fire-proofing character. This will probably be discussed at another time when we follow this line of work further. It is getting a little late and we will hear the next discussion which was written by Capt. J. A. A. Brown, of the Bureau of Inspection of Pittsburg. Mr. Brown is not here, and I believe Mr. Hirsch has his written discussion on the matter.

Mr. Hirsch—As announced in the notices sent out for this meeting, the Programme Committee had arranged with Mr. H. B. Chess, of the Central Expanded Metal Co., for a paper on "Concrete and Expanded Metal Fire Proof Construction." This paper was to illustrate many interesting features in the application of these materials in the construction of floors, partitions, etc., but at the request of Mr. Chess was postponed until some future time.

To the President and Members of the
Engineers' Society of Western Pennsylvania.

Gentlemen—I respectfully submit some points briefly noted concerning the building laws of the city of Pittsburg. Also a few observations along the line of building, relative to high buildings, or as they are commonly called, sky-scrapers; their construction, stability when tested by fire, and their longevity.

The laws governing the erection of high buildings are councilmanic ordinances. Their legitmacy being an Act of Assembly, approved June 7th, 1895. All other points pertaining to the construction of buildings, the creation and building of party walls etc., are also provided for in this Act of Assembly.

The laws governing the construction and kinds of materials to be used in all buildings, other than dwelling houses,

provide for three classes; based upon a limiting height for each class and are as follows: common construction, slow burning and fire proof.

All buildings sixty feet and less in height, are of the third class, and may be of common construction. The term slow burning, the second class, applies to all buildings over sixty feet and less than ninety feet in height, and in which all the members carrying loads and resisting strains are of wood, with the following minimum dimensions: beams or girders, sectional area 8 x 10; posts 10 x 10, to be solid and in no case built up, and having all corners rounded to a radius of at least two inches.

It is my opinion, and I base it upon actual experience, being in attendance at all large fires, that for buildings where much combustible material is stored, such as ware-houses, and especially storage-houses, the slow burning construction is far superior to any other.

For example, about a year ago a fire occurred in one of our nine story buildings of the slow burning class, starting on the eighth story. The building was packed with furniture from bottom to top and the goods in the three upper stories, were practically burned up. On the seventh floor was stored a very large quantity of chair materials, packed from floor to ceiling. This material was all consumed, leaving on the floor ashes or charcoal from sixteen to eighteen inches in depth. The wooden beams or girders of the floor above the same being 10 x 14 in size were only partially destroyed; some of them burned only half way through, none of them entirely. The fire in this story burned fiercely for about four hours.

Then again, the term fire proof construction, which is of the first class, applies to all buildings over ninety feet in height, in which all parts carrying weights or resisting strains, all stairs, elevators, roofs and partitions are made entirely of incombustible materials, and in which all metallic structural members are protected from the effects of fire by means of

some incombustible material, which must be a poor heat conductor. These materials may be either terra-cotta, brick, plaster on iron, or metal lath and iron furring on concrete.

I believe that our fire proof buildings are the equal in matter of construction to similar buildings in other cities, so far as they relate to office and hotel structures, having the rigidity of steel frame, and the necessary fire-proofing. But I also believe that the same system of fire-proofing in buildings that are used for ware-houses and storage-houses, where immense quanties of combustible goods are kept, in the event of fire they will stand the test.

Heretofore we have had no law that made it obligatory on owners of high buildings to equip them with necessary stand-pipes, automatic sprinklers, and other appliances for fighting fire. Such an ordinance has now been framed, and submitted to the City Councils for enactment. Some owners have of their own volition so equipped their buildings.

Much has been said and written, and many times the question is asked, what is the life of a steel frame building? To my mind it is an easy matter to ask the question. But the answer. Who can give it?

The supposition among the majority of persons interested in buildings of this construction, is, they are monuments that will stand for ages, provided they are not destroyed by fire, or razed for other reasons.

Now there is no doubt in my mind, that as they are now constructed, these buildings will stand many years. But not for ages.

About two years ago it became necessary to open up or strip the stone work from a steel corner column, which had been in position about ten years. The surface of this column was found to be, I would say, badly corroded, paint all gone and large rust scales peeling off. Then again in another building we had occasion to uncover the steel floor beams in an outside wall, the beams being encased or fire-proofed with brick.

Here again corrosion had gotton its rusty work in to a great extent, and only nine years in doing it. Gentlemen you can draw your own conclusions.

Of course it is indisputable, that if steel frames were bedded in cement or concrete of sufficient quality and quantity, to entirely exclude the air and gases, then our high buildings or sky-scrapers would be in condition to better stand the test of time, and in reality be monuments to the owners and builders for ages to come.

Respectfully submitted,

J. A. A. BROWN,
Superintendent Bureau of Building Inspection,
City of Pittsburgh.

MR. ALBREE—Now gentlemen, the subject is open for discussion and there ought to be a lively discussion on it. It is now a few minutes after ten so we will have to limit the discussion to not over five minutes. Perhaps Mr. Affelder, of the American Bridge Company will discuss the matter of steel construction. He is a representative for one of the largest steel constructors in that kind of work.

MR. AFFELDER—Mr. Chairman, I did not know of this meeting, not being a member of this Society, and I did not come here prepared to make any remarks. There are a great many things which could be said, but the ground has been fairly well covered in a general way. I think one of the most important things that has been brought out in the meeting this evening is the relation between the architect and the engineer. In my line of work we experience considerable trouble along those lines. Not with the architect who has work enough to employ an engineer to do that portion of the work which is of an engineering character, but with the architect who uses the Carnegie or any other hand book in lieu of an engineer. Such handbooks are very valuable if used by those who know their value, but they may do a great deal of harm. I am in a position

to see a great many plans which are drawn by architects and engineers which, perhaps, would not stand very close examination. I recall one case which I had some years ago in which the architect desired to put a ceiling over the room and his spans between trusses were greater than he could well take care of by using single beams. He, of course, resorted to a trussed beam but as trussing would ruin the appearance of the ceiling if it projected below the ceiling line, he inverted the beam. That is one of a great many criticisms which an engineer may make of an architect. When an architect cannot afford to employ an engineer to assist him in that portion of the work with which he is not familiar, of course, results are very poor. A great many architects will build a combined steel and wood structure (this does not come under fire-proofing construction) by which he will have a system of beams running longitudinally through the building and into these he will frame wooden joists. The architect does not support these bents of steel frame work by steel struts, but allows the wood work alone to support the columns. In case of fire, the tendency will be to burn out the joists and the rest of the system will collapse.

MR. ALBREE—It is just such discussion that is of great advantage to the Society. Anything that can increase the good relations between the engineer and architect, or the engineer and the public in general, by which errors may be reduced to a minimum will be a worthy object of this Society. If we do nothing but make such harmony the Society will not have lost its object in the world. We have with us Mr. Clark, who has had a great deal of experience with building work in general. Perhaps Mr. Clark will say something on the subject.

MR. CLARK—I will have to contradict that statement. My experience has not been in fire-proofing buildings, and in fact, building of any sort. In my work at the Union Station I have had very little to do with the building proper, and do not feel like discussing the question.

Mr. Albree—The meeting is open for general discussion.

Mr. Flanagan—My ideas have been changed a number of times in the last few years. It is not a great many years ago that the Hamilton people put up a building on Fifth avenue, and put a little tower on it. It was one of the sights of the city to go up in that tower and look around. That building is small in comparison with others that have gone up since. When the Carnegie building was being built, I was speaking to a letter-carrier, and he said he was anxious to get the Carnegie building, as it would be a whole established town by itself. That was the first time I thought anything about the advantage of a large office building in regard to distributing mail. Just before the cap-stone was placed upon the Court House tower, I had the good fortune to climb up there and look around, I thought it was a good fortune then because it was the highest thing in sight. Everything looked small from that vantage point. The other day I was in the Frick building. I was not on the top floor either, and looked down upon the Court House and it begins to look small. There is one drawback and that is the big crowd at the noon hour. Anyone who has business down town will wonder what is going to be done when we get a few more Carnegie and Frick buildings to belch forth their crowds at that time. If the streets could be made wider it would be a good thing, but we cannot do that. It would be a good thing to bear in mind that the wider the streets can be made, the better they are. Penn avenue in the East End is the most suitable place in Pittsburg, for high office buildings at the present time. I notice that many of the under-writers prefer wooden shutters covered with heavy tin to the iron shutters, and also that they favor what has been termed slow-burning construction over the massive steel columns and girders, and in some cases the floors have been designed with joists placed solid, side by side, which they say will withstand almost any fire that is likely to take place. I would like to ask those who are

familiar with the construction of office building steel frame work, why it is there is so much heavy material still used in them. You see a building go up twenty to twenty-five stories high which carries the granite even to the top floor. It has seemed to me that perhaps the weight of the material might give stability to the building.

MR. WHITED—As to the point the gentleman last brought out, it strikes me that stone is put on entirely for ornament; it does not add anything to the stability of the building. You will see sometimes massive arches supporting the load above, in which there are columns ten inches square and several feet high. There is an iron beam above it which prevents it from falling down.

I remember one place in the Palmer House, the front entrance is a system of two arches with a column between. As to the durability of these structures, I think there is a great deal to be said; and I think the chemists could throw some light on the subject. There are two phenomena in connection with corrosion. The iron is a hydrate of iron and as near as I can make out, that hydrate, as it is formed ordinarily, is something like four times the thickness of the iron of which it is formed; so that if the iron work is closed in in such a way, the expansion of the iron will produce cracks that are visible long before the metal has corroded to any dangerous extent at all. The expansive force of iron is very great; in fact, it is irresistable. That is to say, if there is not room for hydrate to be formed, it will not be formed. So that if the fire-proof covering is placed closely against the iron, this rust cannot be formed without displacing it. If $\frac{1}{16}$ of an inch of the iron is consumed in corrosion, the result will be that the iron hydrate will have a thickness of about $\frac{1}{4}$ of an inch. That will produce cracks in the fire-proofing that will be visible. The thing to my mind is a rather formidable question. If it is practicable, I would prefer cement to be put against the structure. I have seen Portland cement used for surrounding

iron work and I have seen it crack off. If the concrete is made rich enough so that it lays close against the metal and leaves no spaces for water to work in, it will be an absolute protection. Another fact, the formation of hydrate of iron is an acid process. It takes place much more freely in the presence of acids. In fact, it does not take place at all, only in the presence of some kinds of acids. Cements are all the products of alkalines. If the mortar is rich enough, it will protect the metal if it is so made, that water cannot work between. I do not mean to say that this whole thickness of the fire-proofing must be made of Portland cement, but the part lying next to the metal, however thin it may be, if it could be made of that, it would prevent any dangerous corrosion.

A MEMBER—Our friend, Mr. Wight, speaks of the use of wired glass. He refers to the question of breakable glass over elevators. A question has just come on that line which has been brought to my notice. The elevator shaft I refer to contains four cars and the owner was compelled to close them permanently with wired glass. Since then all the openings in the building have had to be closed up and the building has become almost unbearable on account of the heat. It was decided to open up this elevator shaft and let the heat escape. But what about the fire risk? You are going to increase the fire risk and will have to pay more for it at once. What will we do, let the tenants suffer from the heat? The matter of ventilation is a question made almost prohibitive by insurance companies. It seems to me that the question of insurance people compelling owners to be protected by closing up the elevator shafts by the use of wired glass indiscriminately and making the building almost uninhabitable, is worthy of some thought.

MR. ALBREE—Mr. Wight, there have been two questions brought up that you have perhaps something to say about. One is by Mr. Whited as to rust under ordinary clay fire-

proofing. The other is this point in regard to wired glass. That seems to be something rather new to most of us.

Mr. Wight—Gentlemen, if you feel that you would like to hear something on this subject, I will consent. I want to say this, however, that I have tried my best in a great many talks, to avoid this question of corrosion of steel. I have not the least fear myself about it, and a great deal of this talk about corrosion is sheer nonsense. We can measure it to a certain extent, by noticing the effect of the atmosphere on exposed sheet metal. For instance, if you notice sheet iron, you know just what its thickness is, and when that is corroded, it is corroded on both sides. A great deal of thin sheet steel does corrode, and invariably when used in connection with sulphate of lime, which is contained in the plaster, and which attacks it very readily. I know of plenty of it that has completely disappeared. This steel is extemely thin, mostly 24 or 26 gauge. Now when you take thicker grades, you have a certain index of the amount consumed in corrosion on both sides, and if you take the result of this, you can make some estimate of the time it will take the material to injure the strength of the structural steel. For my part, I never thought it was worth while to take the time to make the calculation. In extreme cases I have seen I beams taken out of a building, which were put in in 1858, which were exposed to leaking water from 1858 to 1870. That is 12 years. I do not count the time after that. During those years I do not think there was a particle of corrosion in the parts of those I beams not exposed to leaking water. In the parts exposed to leakage which I measured there was not more than 1/16 of an inch of loss on both sides. They were beams used to support a water-tank in Chicago. A water-tank is always sweating and is always damp. I call that an extreme case. I do not know of a worse one. In the center, I could not see any deterioration at all. They were just as good as when they were put in. That is all I have to say about corrosion of steel. I think

there has been some food on this subject furnished to newspapers who have a desire to fill up their columns. As all these large modern buildings are heated by steam, there will never be any corrosion. I would like to know where there is one of them that water can penetrate. If the steel is exposed in few little spots, these spots may deteriorate, but that does not make the buildings unsafe. I know of one case where a building inspector found a piece of corroded steel, and wrote to the newspapers about it. That had probably been wet and dry at times, and he made a great talk about it, and got a great deal of advertising. I do wish scientific men and engineers would take up the subject, and put a stop to the foolish talk. If the threatened famine in steel comes, we will have to go back to the old way. A steel skeleton is not an absolutely necessary thing. You can build floors without any steel except a few rods. I have some photographs of them. Sections of floor 16 x 18 feet have stood a test of 700 pounds to the superficial foot, distributed load.

About that wired glass, now I do not say what I do because of the building laws of Chicago. They require that there must be a skylight over the elevator shaft. I would put in double-thick sheet glass and I would use the kind that would not take much heat before it would break. There should be wire screens over the glass that will resist hail stones. Fire is a very dangerous thing and if it wants to go up, help it go up and get rid of it. There have been two fires in the Great Northern Hotel in Chicago, and little harm has been done. There are so many fires in fire-proof buildings in Chicago that I have stopped making any record of them. There was a fire in the Annex Hotel last Wednesday. It burned out one room. They pulled out about forty blankets and the fire got so bad they shut the door and stood watching it with a hose in their hands. The fire burned itself out, and they had no panic about the building. It is a good building. It stood the fire. No other than a fire-proof building would have stood it. I

know one building in Cleveland where they had five fires in a year. It is perfectly astonishing the number of fires in these buildings. But good fire-proofing has saved them.

With reference to insurance, I do not think I will waste my time discussing it. I do not think insurance has ever had any effect on building. In fact, without insurance all buildings would be made fire-proof. Every man tries to make his building as bad as he can provided he can get it insured. We have fire-proof buildings some of the most dangerous kind and others of the best kind. The building law in Chicago requires that there shall be a large ventilator over the stage in every theatre ; which is, to produce a draft in order to keep the fire from going down into the auditorium. Every theatre that has been burned where this is provided has been burned in the direction of the stage, not in the direction of the audience. There was one burned right under my window. The energy of the fire was on the stage end. The whole tendency of the fire was to go that way.

Mr. Hirsch—I would like Mr. Wight to tell us something about the settling of steel buildings in Chicago, on account of the compressible nature of the soil.

Mr. Wight—The modern system is to build on concrete wells. Grill foundation is practically out of use in Chicago. There is no settling of buildings on the well foundations. These wells go down about 90 feet, where they reach a hard ground which cannot be removed without dynamite. It is below this where all water tunnels are bored. There are four bored out four miles into the lake, and connected with the cribs. That is where we get our water supply. There has never been any settling on any good job, where concrete wells are used. Settlements of buildings which are built with the so called floating foundations have been various. They vary in different buildings. Most of them have 4,000 pounds weight to the superficial foot. I know some of them must have more. This variation in settling is due to two things. The

formation of the clay is not uniform. It is generally uniform under each building. It is my opinion that there has been a great deal of inaccuracy in the calculation of the weight of these buildings. However, we need not be so careful now since we use wells. I used old iron rails at first. In that instance we put in a foundation and computed at 4,000 pounds superficial weight. During the year afterward that building only settled 1¾ in., and we kept the building next door on screws. We put them on the edge of our new foundation and as our building settled we screwed the old one up. After five or six years I noticed that the building next door showed cracks. The new building has settled, I think, about three inches since then. Parts of the City Hall, they say, have settled 18 inches. There is an aggregation of buildings there which consists of the Great Northern Hotel, Theatre, Office Building, and Majestic Building, which were all built at different times. The greatest care was taken to proportion the foundations of these several buildings, all designed by the same architect, so that they would settle equally. But the result was not entirely satisfactory and demonstrated the difficulty in erecting adjoining buildings on a compressible soil. The use of concrete wells has overcome this difficulty in more recent structures.

MR. ALBREE—In line with the present discussion of high buildings, it is hoped by the management to obtain permission from Mr. Frick within the next week or two, for the Society to go through the Frick Building some evening, especially to see the power plant, and we have an invitation from one of the large tenants of the building to make use of their rooms, and we hope to have one or two short papers to read at the Frick Building, which will make our visit to the subterranean regions more interesting.

For our next meeting we will have a paper by Mr. Clark, who is with us to-night, regarding some features of the Union Station work.

If there is any other business we will take it up now.

MR. HIRSCH—As Chairman of the Programme Committee, I wish to say a few words. There is considerable labor involved in arranging for these papers, but it has been a pleasure to me on account of the courteous manner in which I have been received by these gentlemen, and the members of the Society. The large number of excellent papers which we have been able to present at these meetings is very gratifying to the committee, and I will ask the Society to pass a vote of thanks to these gentlemen for their very interesting papers. When they are printed in our proceedings they will make a very interesting series of papers.

I move that a vote of thanks be tendered these gentlemen for their excellent papers. Motion carried.

On motion the Society adjourned at 11:05 P. M.

CHARLES W. RIDINGER,
Sec'y.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held Thursday evening, May 22, 1902, in the rooms of the Society, the chairman, Dr. K. F. Stahl, presiding. The evening was devoted to discussion of the new By-Laws, submitted by the committee appointed to draft them. Professors F. C. Phillips and Mr. Wilkins. After amendments and corrections they were adopted by vote of the Section and the commitee commended for the prompt and able manner in which it had fulfilled its obligation.

On motion the Section adjourned.

CHAS. H. RICH,
Sec'y. C. S.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and twenty-sixth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's house, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, June 17th, 1902. The meeting was called to order at 8:30 o'clock, with the Vice-President, Prof. F. C. Phillips, in the chair, and eighty-nine members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership, and presented the same to the Society for action:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
LOUIS J. AFFELDER,	Contracting Engineer, - American Bridge Co., 826 Frick Bldg., Pittsburg, Pa., h., 1211 Sheffield St., Allegheny, Pa.	R. C. Falconer, C. W. Ridinger.
JOHN M. DAVISON, -	Civil Engineer, - - American Sheet Steel Co., Pittsburg, Pa., h., 1215 Buena Vista St., Allegheny, Pa.	H. H. Anderson, Sumner B. Ely.
VICTOR E. EDWARDS,	Mechanical Engineer, - Morgan Construction Co., Worcester, Mass.	C. B. Albree, Sumner B. Ely.
WILLIAM J. HARRIS, -	Manufacturer, - Prop. Wm. Harris & Sons Forging Co., P. O. Box 1082, Pittsburg, Pa.	John Hare, John W. Landis.
FRANK C. IRVINE, -	Engineer, - - C. & M. Railway, Economy, Beaver County, Pa.	Geo. C. Urquhart, Edmund Yardley.
HUGH D. KIMBER,	With W. G. Wilkins, - Westinghouse Bldg., Pittsburg, Pa., 304 Colonial Bldg., Wilkinsburg, Pa.	Wm. Glyde Wilkins, C. W. Ridinger.
CHAS. R. MILLER, -	Clerk, - - - Purchasing Dept., Carnegie Steel Co., Pittsburg, Pa., h. 250 Atlantic Ave., Pittsburg, Pa.	Henry W. Fisher, C. W. Ridinger.

... Engineer ... Charles F. Scott.
Francis Hodgkinson
... East Pittsburg, Pa.

... Gen. Mgr. ... Charles F. Scott
Chas. W. Ridinger
... Swissvale, Pa.

... General Superintendent ... W. E. Snyder
W. M. Judd.
... Pittsburg, Pa.
... Pittsburg, Pa.

... Draughtsman ... L. E. McClelland
Francis Hodgkinson
... Pittsburg, Pa.

... Draughtsman ... L. E. McClelland
Francis Hodgkinson
... East Pittsburg, Pa.
... Pittsburg, Pa.

... Electrical Engineer ... Charles F. Scott,
E. P. Davis.
... Pa.
... Pittsburg, Pa.

... H. Hunter, Jr.,
Charles F. Scott.
... Pa.
... Pa.

... W. E. Snyder.
W. M. Judd.
... Pittsburg, Pa.,
... Pittsburg, Pa.

MR. ALBREE—I move that the Secretary be requested to cast the ballot for the election of the gentlemen whose names have been read.

PROF. PHILLIPS—We have authority, by the new By-Laws, to vote on applicants who have been proposed at a meeting of the Board. It is not necessary for them to be held over for a month, if the names have been posted previous to presentation to the Society for action.

Motion carried.

The Board of Direction recommends that the Society authorize the Reception Committee to make necessary arrangements for a Smoker to be held Thursday evening, July 3rd, for the entertainment of the visiting members of Sections C and D, of the American Association for the Advancement of Science, and that the Society members attending the Smoker be requested to pay $1 each.

PROF. PHILLIPS—Of the visiting scientists who are to be here towards the end of the month, there are two sections of the American Association for the Advancement of Science. It is probably due them that this Society show them some special courtesy, and this resolution has reference to the section of Chemistry and Engineering. Will you recommend the Reception Committee to take steps to provide a smoker as they are recommended to do?

MR. JOHNSTON—I move that the Reception Committee be instructed to proceed with arrangements for a Smoker as outlined in that resolution.

Motion carried.

PROF. PHILLIPS—Are there any reports of special committees? Mr. Johnson, have you any report to offer on the reception of the coming visitors?

MR. JOHNSTON—Mr. Chairman, I would like to ask if any steps were taken to carry out the suggestion to tender the use of these rooms to the engineers and chemists in attendance at the meeting of the American Association.

PROF. PHILLIPS—I think nothing was done.

MR. JOHNSON—I would make a motion that the Secretary be authorized to tender the use of these rooms to the Engineering and Chemical Sections of the Association during their meeting.

Motion carried.

PROF. PHILLIPS—I have just receivd word of the death of a member of our Society, Col. T. B. Nichols.

We come next to the reading of the papers, of which we have several important ones this evening, in regard to the erection of the Union Station. The first one is "The location, preparation of site, approaches, elevated tracks and train sheds," by Mr. G. C. Clark.

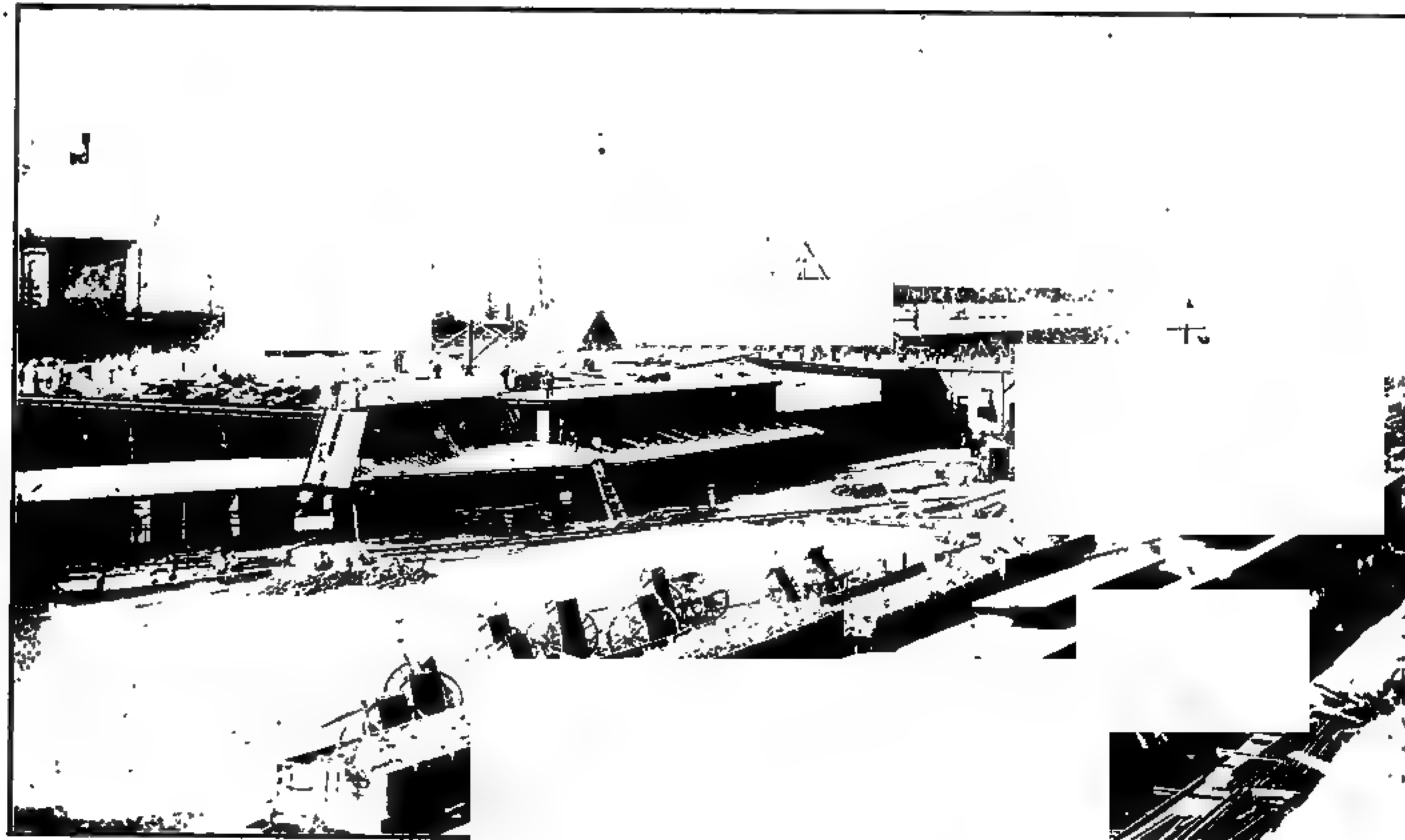

Photo No. 1.

THE NEW UNION STATION P. P. R., PITTSBURG, PA.

THE LOCATION, PREPARATION OF SITE, APPROACHES, ELEVATED TRACKS AND TRAIN SHEDS.

BY MR. G. C. CLARK,

Assistant Engineer of Construction, P. R. R., Pittsburg, Pa.

When it was decided to build a new Union Station at Pittsburg with more commodious rooms for the traveling public, more tracks, and longer tracks in the train shed, and an approach from the west that would do away with the dangerous crossings at Liberty avenue and 11th street, and at Penn avenue, the first questions to be decided were location, size and elevation of train floor.

The different roads approached the old station on the following grades and lines. The main line and the Buffalo and Allegheny Valley Division of the Pennsylvania R. R. directly from the east on a descending grade of 0.9 ft. per 100 from 17th street, to the west end of the train shed. From the west on the north side of the station, the Pittsburg, Fort Wayne & Chicago Railroad crossing the streets before mentioned at grade, approaching on an 18° curve and a level grade. The Duquesne freight track coming up Liberty avenue, and joining the Fort Wayne road at the west end of the old station. To the south of the station the Pittsburg, Cincinnati, Chicago and St. Louis Railroad and the Monongahela Division of the Pennsylvania Railroad approached from the west through the Try street tunnel. We have then as the determining points Liberty street, one of the principal streets of Pittsburg, on the north at an elevation of 743 feet, on the south the Grant boulevard, approximately parallel to Liberty street, and 400 feet distant therefrom at an elevation of 807 feet, or 64 feet above Liberty street, at the west end of the station, and rising rapidly toward the east until it reaches an elevation of 916 feet, or 173 feet above Liberty at 17th street.

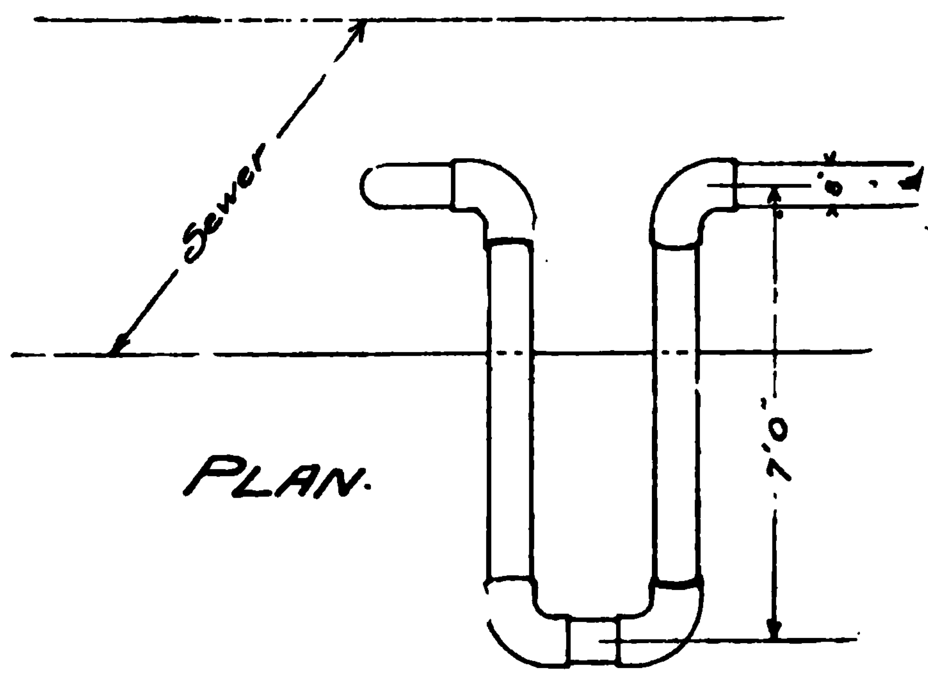

FIG. 1.

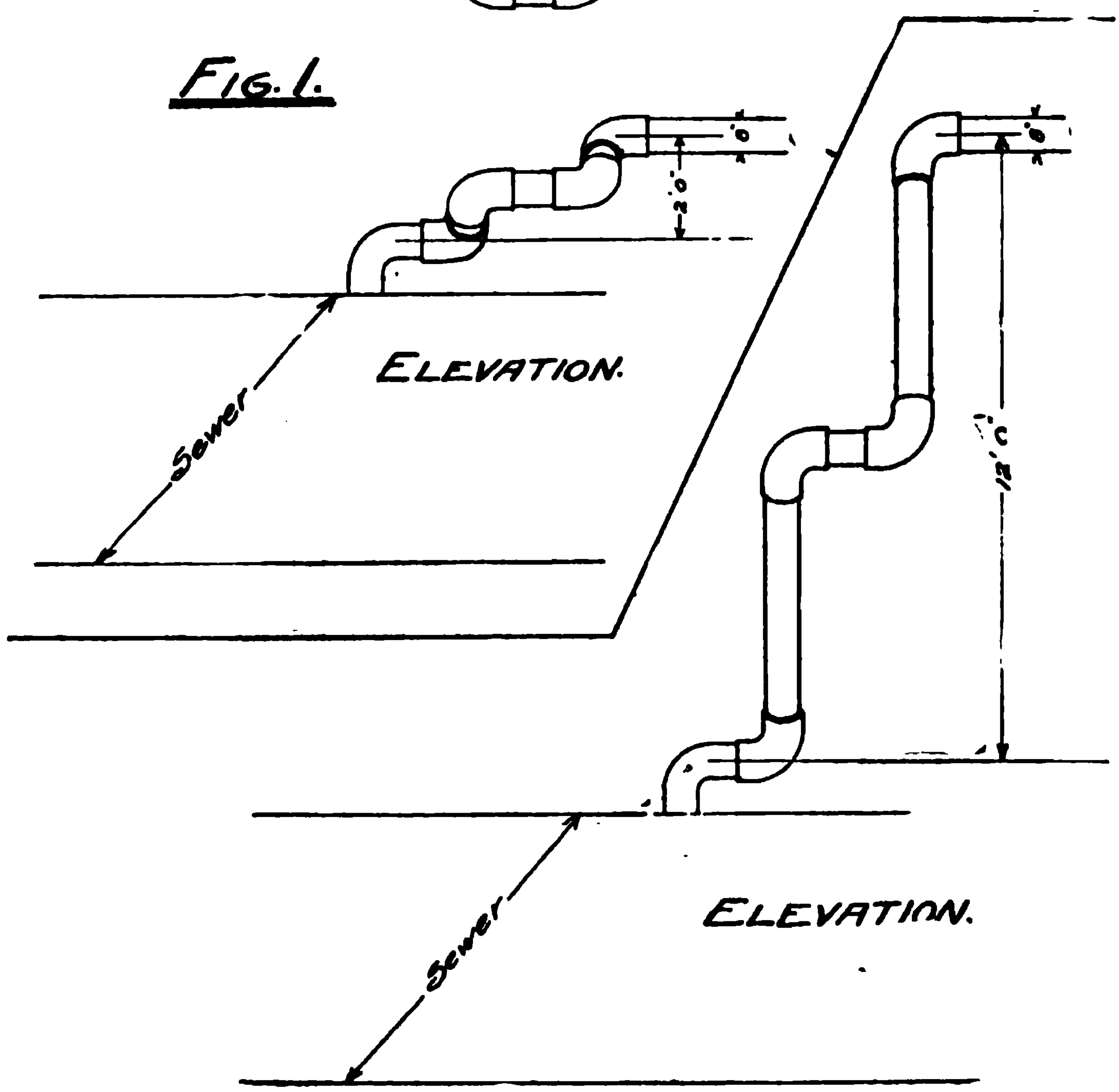

FIG. 2.

The boulevard being supported on the north side by a retaining wall having the foundation opposite the east end of the old station at an elevation of 777 feet, or 34 feet above Liberty street, and rising gradually until at 17th street, the elevavation of the bottom of foundation is approximately 895 feet, or 152 feet above Liberty street. To the west we have at a distance of 1150 feet from the east end of the old station, the Try street tunnel at an elevation of 743.3 top of rail, or about that of Liberty street. The width of the station is then determined by the distance between Liberty street and the Grant boulevard and the following facts. There must be one track on the north for the Duquesne freight; there must be two tracks for the Fort Wayne freight trains, which shall not be interfered with by Passengers trains standing to load or discharge passengers; there must be at least three tracks for the use of these passenger trains; the P. C. C. & St. L. and Monongahela Division trains must have at least as great a number of tracks to the south of the station. Bringing these tracks together as rapidly as possible after leaving the starting point, we find 175 feet as the maximum width for the station proper. Since it is necessary to have eight tracks for the use of the Eastern traffic, making the total number of tracks at the train shed twenty (20) and remembering that the farther east we go the higher the boulevard becomes, and the greater the distance the tracks must be kept from it, we see that the farther west the station is kept, the better. In this direction, however, we find Try street tunnel which must be gone through, and Liberty street which is to be crossed overhead. Taking a maximum grade of 1 % from Try street tunnel, and lowering Liberty street as much as possible without damaging the property on that thoroughfare, we find the most western point at which the Panhandle and the Fort Wayne tracks can be brought to the same elevation to be 100 feet east of the old station and at an elevation of 755.8 feet.

PHOTO No. 2.

Since it is very desirable for the convenience of passengers, and almost necessary for the interchange of baggage to have all tracks at the same elevation along the platform, this point determines the location of the east end of the station lobby and the elevation of the train floor.

PREPARATION OF SITE.

Work of preparing the site for the head house or station proper was begun in March, 1900. The first step was to shorten the tracks in the Grant street freight yard, and put in new connections with the main track. Second, to tear down the old P. C. C. & St. L. round house and the retaining wall from that point to the Try street tunnel and to grade this ground down to the elevation of the new tracks. The old station being on the ground to be occupied by the new one, it was necessary to provide temporary quarters and tear down the old building before any progress could be made towards erecting the present one. The west end of the train shed was therefore taken down and a rough frame building 200 by 80 feet was erected on the space thus obtained (see photograph No. 1). This building contained all of the essentials, though few of the comforts, of a first class passenger station. Waiting room, dining room, restaurant and kitchen, baggage room, ticket offices, both railroad and Pullman, mail rooms, womens' waiting room, barber shop and toilet rooms. Perhaps the only thing worth mentioning about the construction of this building was the plumbing. As it was desired to raise it along with the tracks while it was occupied (see photograph No. 2), the supply pipes, soil pipes, aud steam pipes had to be arranged so that no breaks or leaks could occur while this was in progress. In order to provide for this, connections were made as shown on Figure 1.

These pipes were supported by stirrups fastened to the floor of the building and the connection was supported by blocking as the station was raised; until, at the end of that

operation, the elevation of this connection was as shown on Figure 2. This building being completed the traffic was turned into it on the 5th of July, and the razing of the old building begun. As about 70,000 people passed through this building each day, the work had to be done with great care. The side walls having first been braced by running 4 x 6 timbers horizontally on line with the middle of the second story windows, and attaching to these other 4 x 6 timbers which ran through the windows and were fastened by posts in the middle of the building, and below the level of the second floor. A track was laid from the west down the middle of the building, in what had been the waiting room, and as the material was torn down it was loaded into cars and shipped away. This work was finished about July 20th. A high board fence was then placed about the site and the work of excavating for the foundations begun.

CONSTRUCTION WORK OUTSIDE OF BUILDINGS.

Under this head will come:

Track raising.
Retaining walls.
Face walls.
Tunnels.
Bridges and Viaduct north of station.
Train shed.

Had this amount of work been done in the open country, with nothing to contend with except nature, it would not be worth your while to listen to an account of how it was accomplished. But when you consider that the space in which this work was done was not sufficient in an untrammeled condition for the business which was carried on, and that 261 regular passenger trains carrying 100,000 people not only came and went, but were made up in this space daily, and that 90 freight trains daily passed through this yard, we think that you will realize that only a journal of troubles could describe all the

makeshifts that were resorted to in order to prosecute the work without entirely closing down this end of the Pennsylvania system.

TRACK RAISING.

As we have mentioned in describing the location of the Union Station, the elevation of the tracks at the east end of it when work began was 743.00 feet, and at 17th St. 761.00 feet. The new elevation of track at the east end of the station is 756.00, and at 17th St. 761.00, the same as previously. This necessitated raising the tracks, platforms, signals, gas and water pipes which supplied cars in the shed, an amount varying from 0 at 17th Street to 13 feet at the east end of the station. This raising covered an area of more than ten acres, and required 100,000 cubic yards of material to be put under tracks and platforms. The material used was that excavated from the hill south of the station to make room for more tracks. This was slate, rock and clay. The work could no doubt have been done more rapidly with cinder, but now that it is finished, the fill is much more satisfactory than one of cinder could be, as the latter would continue to settle for a long time, and there is always danger of a smouldering fire in cinder used over any great area. The track room in the old station was so limited when at its best that it was not thought possible to take up any tracks while this raising was being done, and the following plan was adopted. Let me first explain that there are two periods in each 24 hours when the traffic, both through and local, is very much heavier than at any other, from 5 A. M. to 9 A. M., and during the same hours of the evening. During these eight hours of the day, the capacity of the yard was taxed to its utmost and nothing could be attempted. As soon after this busy period as one track could be cleared, a large number of men were put on it and it was jacked up about one foot, and blocked in that position with ballast or rock. When this was done, and the track next to it could be cleared, a train of mud cars

was placed on this second track and the material shoveled on to the first and rammed under the ties. This same action was repeated by the next shift, except that the train stood on the first track and the second was raised. The platforms were lifted at the same time, being held up by wooden blocking, and the filling kept about 4 feet below the platforms to allow room for men to work until they were raised to the desired height, when they were filled to a level with the material under the tracks.

RETAINING WALLS AND FACE WALLS.

Strictly speaking, there were but two retaining walls built. One running from Try Street Tunnel to the Washington Street foot bridge, 600 feet long and 22 feet high above the footing course. This wall is built upon stiff clay capable of sustaining a weight of four tons to the square foot with safety, while the greatest weight put upon it is two tons. It has a footing course of 4 feet of concrete mixed, as is all other foundation concrete at Union Station:

1 part Cement.
2 parts Sand.
5 parts Broken Stone.

This concrete was mixed very wet and well rammed, and was allowed to take its initial set before the stone work was placed on it. The width of the wall on top under the coping is 3.5 ft. and at the bottom of the neat work 11.5 ft. The bottom width being calculated from the following imperical formula:

$$W = \frac{2h}{3} - 3'$$

in which W = width at bottom and h = height of wall above neat line. This gives a wall quite sufficiently strong where the height is over 18 feet. Where it is less than 18 feet the constant 3 becomes too large in proportion to the other factors, and the formula is changed to $W = \frac{1}{3} h + 3$. For the height of 18 feet these two formula will give an identical value for W.

The only difficulty encountered in building this wall was that caused by working in a very cramped space due to the proximity of the Panhandle tracks, and the large amount of shoring necessary to support the Boulevard wall, the foundation of which is of filled material 18 feet above the foundation of the Panhandle retaining wall, and not more than 70 feet back of it at any point, while at the Washington Street foot bridge the face of the Boulevard wall is in line with the back of the Panhandle wall. A much more interesting piece of construction was that of the Liberty Street retaining wall. This extends from the east end of the station to within 200 feet of 17th Street, a distance of 2,150 feet, with a height above foundation varying from 3 feet at the eastern or 17th Street end to 16 feet at the western end, and was built to support the main yard above the Duquesne freight track. The excavation for this wall was made and the masonry built directly under one, and in some places two, Fort Wayne tracks while they were being used by freight and passenger trains. We will describe the method in detail as it was used with slight variation in much of the work at Union Station. Excavation was first made for a short distance under each rail to a depth of about 30″ below the base of tie, the track being supported meanwhile by blocking under alternate ties; then three Y. P. stringers 8″ x 14″ and 24 feet long were placed under each rail and so arranged that no two joints were less than six feet apart.

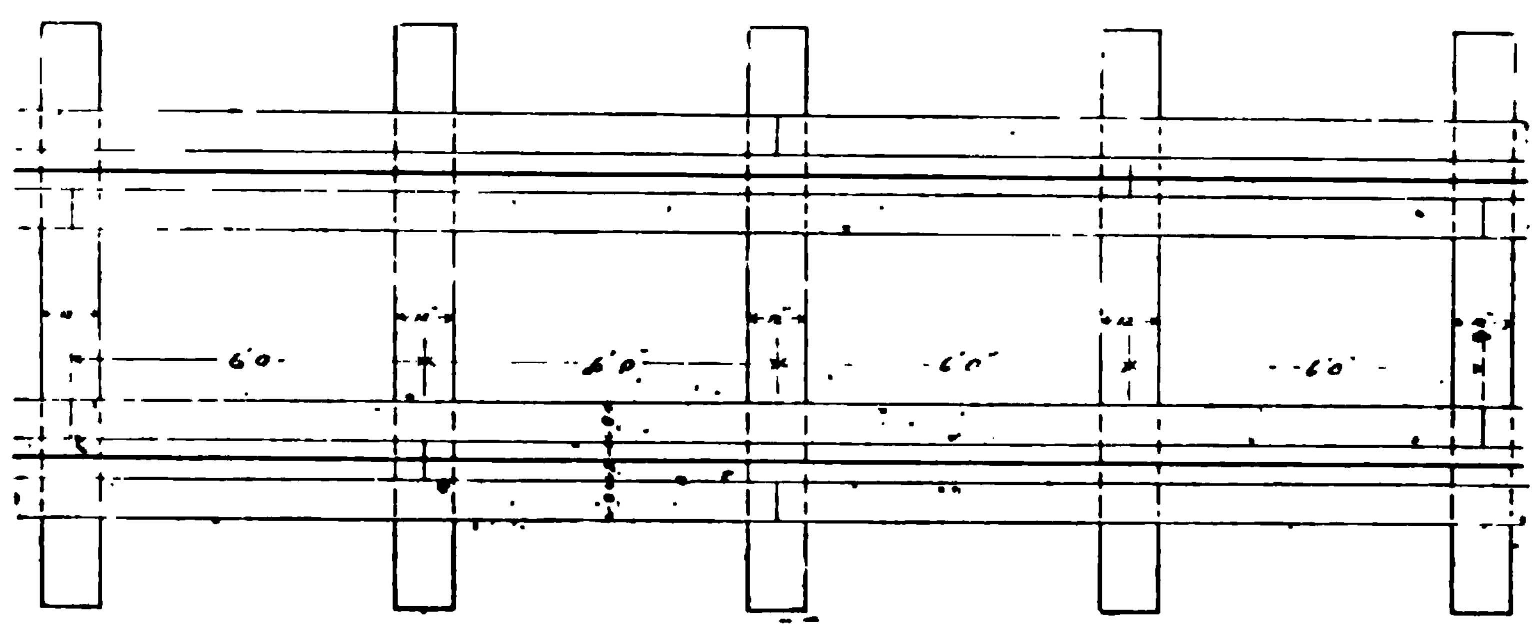

FIG. 3

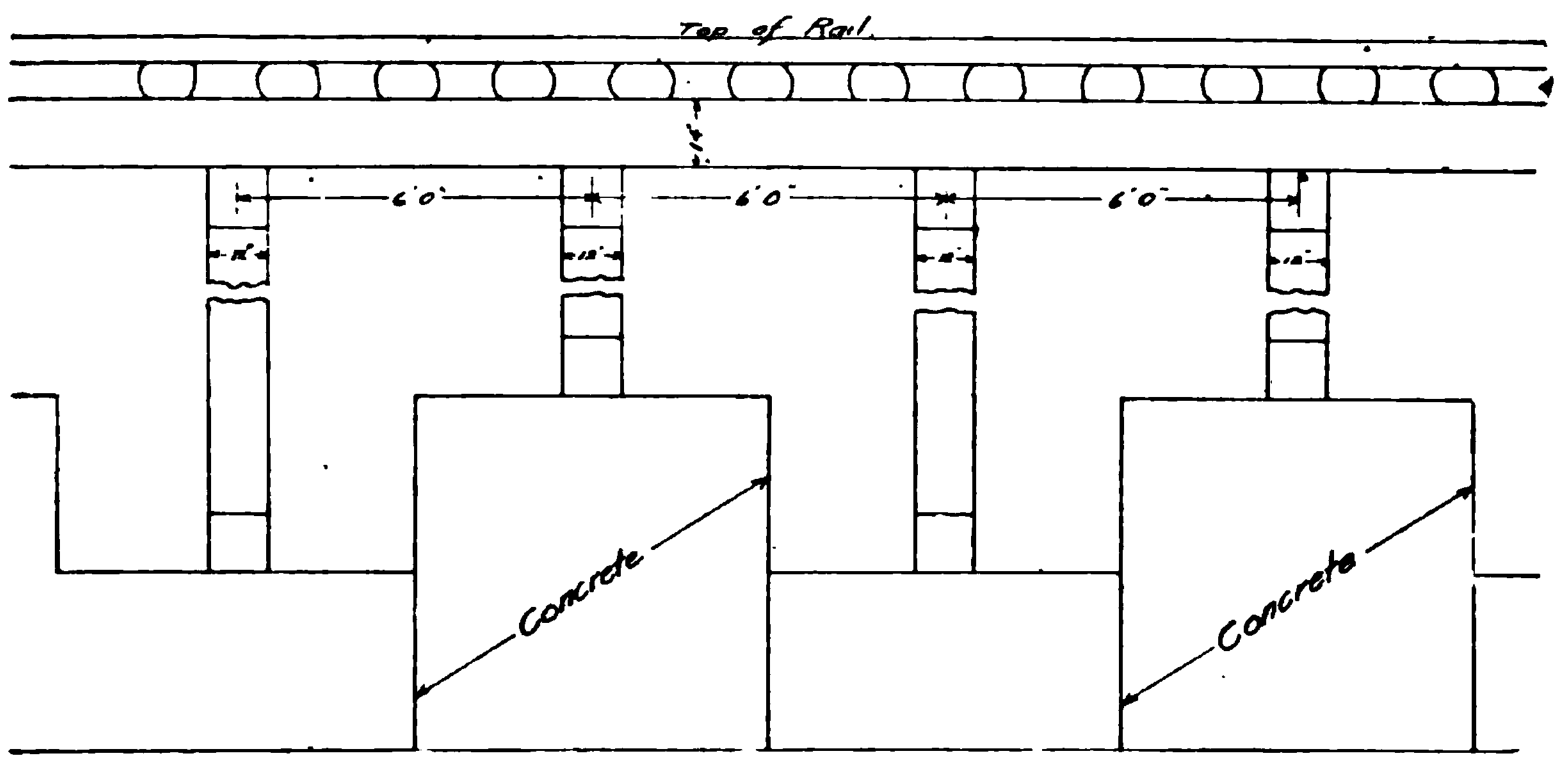

FIG. 4.

12″ x 12″ Hemlock Caps were then placed under these stringers at intervals of 6 feet, each break in the stringers resting on a cap. Every other cap was then firmly blocked up, and the alternate ones allowed to hang free. Excavation was then continued under these free caps, and 3 feet on either side, to a depth of about 6 feet below the base of tie, when a small bent was erected and firmly blocked; taking the weight off the caps which had been resting on blocking. This blocking was then removed and the material excavated to some distance below the sill of the first bent. This distance varying accordingly to the material excavated, and its liability to give way under the pressure. A second set of bents was then erected and the first removed and excavation continued until it became necessary to erect a third and remove the second. When material sufficiently firm for a foundation was reached, the space was filled with concrete to the elevation of the top of foundation, and after it had attained its initial set, a bent was placed on it to support the tracks, figure 4, and the intermediate bents were removed and excavation and concrete finished.

The concrete having been put in to the base of neat work the stone work was begun. Any timbers in the bents that were more than two feet from the face of the wall were built in, those nearer the face being cut off as the masonary was completed.

FACE WALLS.

In order to make room for the desired number of tracks east of the station it was necessary to excavate very close to the boulevard wall, which is built at this point on a foundation of hard slate about 10 feet in thickness and 60 feet above the elevation of the railroad tracks. Under this slate are strata of soft shale and a low grade of fire clay. This material is hard enough to stand almost vertical when first excavated, but weathers very badly, and if unprotected would very soon have fallen away enough to destroy the Grant boulevard, besides

keeping the tracks near it continually covered. To prevent this, a face wall, much lighter than a retaining wall, was built for a distance of about 1200 feet, and as high as the bottom of stratum of hard slate before mentioned. This wall is not more than 12 feet thick at the bottom at any point, and no soft material was allowed to remain back of it. Wherever any pockets appeared, as is alway the case in rock excavation, they were filled in with solid masonry. Weep holes were left where any water seams appeared in the face of the hill. Fortunately these were necessary in very few places, as the principal water course seemed to be through the stratum of heavy slate and just above the top of the face wall. To properly shed this the coping was given a pitch of about 25° and a coating of cement, with a small quantity of sand, put on it, and carried well back against the face of the rock. This has proven very satisfactory, and very little water comes through the wall, although a great deal runs down over it. It was the large amount of water coming through this layer of slate that determined us to keep the top of the wall below it instead of carying it to the bottom of the boulevard wall.

TUNNELS.

The tunnels constructed are five in number; two running between the power house and the station proper, are stone arches of 8 feet span each and about 70 feet long and used to carry pipes and wires for the heat, light, power and water between the two buildings. Of the other three tunnels, two run longitudinally under the platform from the basement of the station to the cross tunnel 720 east, which is in reality a blind street 28 feet wide leading off Liberty street. These three tunnels form an underground system for the handling of baggage, express, and mail matters, thus preventing a great deal of trucking on the platforms, and saving the passengers much annoyance, and the employes much time. The impedimenta handled through these tunnels is brought to the surface by

three direct acting hydraulic elevators placed on the east side of the 28 foot cross tunnel, and so arranged that it is never necessary to cross more than one pair of tracks after coming to the surface to reach any platform in the yard. The longitudinal tunnels are 10 feet wide each, and are simply two stone retaining walls with a roof formed of 9″ I beams and brick arches. Each of these roofs forms the base of a granolithic platform, it first having been covered with 1″ of asphalt mastic to keep out the water. The sides of the 28 foot tunnel are two bridge abutments each 220 feet long and having their foundations about thirty feet below the elevation of the tracks. The roof of this tunnel is formed by five double track half through girder bridges, one single track girder bridge, and one for two tracks of 24 inch I beams. These girder bridges are constructed very much like the Fort Wayne Viaduct which will be described later. Between them run I beams covered with buckle plate, the whole thing making a continuous iron roof, and being covered with concrete and asphalt to prevent leaking.

The method used in constructing the walls was similar to that employed in the construction of the Liberty street retaining wall.

Leading off the cross tunnel there are three rooms 40 x 15 feet and used as follows :

No. 1, Ice house.

No. 2, Lamp and oil room.

No. 3, Coal and Stores for car inspectors.

The ice house has a large chute leading from the track above; each day a car of ice is brought in, dropped down the chute and stored for the following day, when it is broken into convenient sizes, washed and taken to the platforms as needed to ice the cars.

The lamp and oil room has a pit under its floor containing three oil tanks of 500 gallons capacity each, arranged so that they can be filled from a tank car on the tracks above.

These large tanks discharge into smaller ones, from which, by a pressure of five pounds of air, the oil is forced through pipes to the spiggots in the oil room to be used as needed. The room is fitted up with a large number of metal bins or cases.

When a train crew comes in from a trip they take their flag boxes and lamps down to the oil room and hand them over to the man in charge, who first cleans them and fills the lamps, then puts them away in their proper cases to remain until wanted for the next trip.

The arrangement of the coal and store room is similar to that of the lamp room with the addition of a coal bin with a capacity of 60 tons of coal. The bins or cases in this room are used to hold lamp globes of all kinds, tumblers, brasses and all the hundred and one things that are used by car inspectors. By means of these rooms much of the dirt and all of the inflamable material is kept away from the station proper.

BRIDGES AND VIADUCTS.

The bridge over 11th Street and the one over Liberty Avenue are so similar in construction, that it is only necessary to describe the later.

As there is no sidewalk on the south side of Liberty Avenue at this point, the clear width of street between abutments is only 48 ft. The tracks, however, cross at so great an angle from the perpendicular that the actual span is 86.46 ft., and length over all of girders 111 ft. 9¾ inches.

Owing to the sharp curve in the Ft. Wayne tracks at this point, 12° and 45″, the girders are 32′ 9″ centre to centre, for two straight tracks the corresponding width would be only 24′.

This fact, of course, necessitates very heavy floor sections and increases the strain on the girders, the centre flange section of which is 112.02 inches. These two girders being the heaviest, though not the longest, ever built. Their weight is 128,000 pounds each. The floor beams are box girders 26½″

deep by 20¾" wide and set 3' 4½" centre to centre, the spaces between being filled by buckle plate 8" below the top of box girders.

On account of the great skew on which this bridge is built the west end of the north girder and the east end of the south girder are the anchored points. The southeast and northwest corners being on rollers.

The floor of the bridge is filled to a height of 2" above the top of beams with gravel concrete, and covered with 1" of asphalt mastic. The tracks being ballasted as on an ordinary road bed, thus preventing the rumbling so noticable on most girder bridges.

The Ft. Wayne Viaduct is a solid iron floor, constructed of five rows of girders, spaced from 12' to 15' centre to centre, between which run trough sections 12" deep and 10" to 13" wide. Each line of girders is supported by latticed columns varying from 22' to 32' centre to centre.

There is a great amount of riveting necessary in a structure of this sort, as each girder is thus fastened to the columns that support it, and all trough sections are riveted through the supporting girders and to the corresponding section in the next panel.

Like the bridges described, the floor is filled with concrete and covered with asphalt, making a solid road bed and a dry room underneath.

The iron is designed to support the weight of the heaviest locomotive in any position, so that track connections may be changed in any direction desired.

The great difficulty encountered in constructing this viaduct was due to the fact that the old Ft. Wayne tracks occupied the ground on which two of the rows of columns and the southern half of the Liberty Street abuttment, which supports a portion of the viaduct, stands.

The three panels south of these tracks having been erected (see photograph No. 3) the old Ft. Wayne road between

the east end of the Station and the north side of Penn Avenue were abandoned at 10 o'clock Sunday morning, October 6th, and after excavation was made to a depth of 5′ to permit the Duquesne freight track to pass under the elevated structure. Trestle bents of 12″ x 12″ hemlock, with legs placed 4′ centre to centre, were put up parallel to and just off the lines of the girders yet to be erected.

A floor of 8″ x 14″ Y. P. stringers 2′ centre to centre was put on these trestles and the new tracks spiked into position. This work was finished at 1 o'clock Monday morning.

During that period of 15 hours, 1,600 lineal feet of track and a number of crossovers were torn up, 800 cu. yards of material excavated, a good day's work for a large steam shovel, 48,000 ft. of timber erected, and 2,000 ft. of track and two crossovers laid.

The balance of the foundations and superstructure for the viaduct was then built under the trestle work, the timber being taken out as the iron work was completed.

TRAIN SHED.

The train shed, now being erected, is a single span steel structure 258 ft. wide, 556 ft. long, and 90 ft. high at the center.

The arches are arranged in pairs, 9 ft. centre to centre, and 40.6′ between pairs.

Each arch is in reality a bow string truss, the bottom cord being under the tracks and imbedded in bituminous concrete to prevent its corroding. The south end of each truss is anchored, while the north end is on rollers to allow for expansion and contraction.

There is the usual lantern, running the entire length of the shed at the top, and also lateral lanterns over each pair of arches, and midway between them.

There is no glass in the roof proper, all light being admitted through the ends of the shed, and the sides of the lan-

terns. Being in a vertical position, it is much less likely to be broken and to fall out, and in the location of the Union Station train shed, glass in a horizontal position would require constant cleaning, or it would admit no more light than the slag roof.

PROF. PHILLIPS—We will now proceed with the discussion of this paper. Is there any discussion on this paper?

A MEMBER—I would like to ask Mr. Clarke in regard to putting a coat of asphalt on the arch, if that is the best method of making it water tight?

MR. CLARK—It was done just to keep the water from coming through. We were using the ground underneath. I have never seen any cement that would do it. Asphalt will do it if it is put on properly.

A MEMBER—I would like to ask Mr. Clarke for his formula. I did not catch his figures.

MR. CLARK—It has been found by practical use on the Penna. R. R. to be ample. It is a formula that was not used by them until within the last four or five years. It is two-thirds the height minus three feet at the base for a height of more than 18 feet. Under eighteen feet, it is one-third the height plus three feet.

MR. WHITED—In reference to that retaining wall, was that formula only used where the earth is horizontal? When it is a surcharged embankment do they use the same formula?

MR. CLARK—If you have a surcharge of over six feet you would have to increase that.

A MEMBER—Do you not consider a load of trains equal to a surcharge of over six feet?

MR. CLARK—No, I think not.

CHAIRMAN—Is there any further discussion? If not, perhaps we had better proceed to the next paper of the evening, "Designing the Station, Architectural Features, Foundations, Structural Work, and Ornamentation," by Mr. J. G. Giaver, Architect and Engineer, with D. H. Burnham & Co., architects, The Rookery, Chicago, Ill.

MR. GIAVER—Mr. President and members of the Society, I see used here two words, architect and engineer. That is two words, isn't it? I want to call your attention to it. There are animals that can live in the water and on the shore equally well. That is the kind of an animal that is an engineer and an architect at the same time. I am an engineer.

CONSTRUCTION, DESIGN, ETC., OF THE NEW UNION STATION FOR THE PENNSYLVANIA RAILROAD, PITTSBURG, PA.

BY MR. J. G. GIAVER.

In presenting a paper on the construction and design of the Union Station for the Pennsylvania Railroad it may not be amiss to review the progress made in building construction during the last 20 years.

The development in nearly every industrial branch has been phenomenal during this period. The great improvement made in steel manufacture, for instance, as well as in other industries which supply the building trades, has opened the way for progress. In the art of building construction so rapidly has one improvement followed another that buildings considered the height of perfection 20 years ago, are regarded old-fashioned and obsolete to-day. The same may be said in regard to the different elements brought together in a building, many of those now contributing to the success and convenience of the buildings having been unheard of two decades ago.

I will confine myself in this review to what is generally termed "business buildings." Twenty years ago steel was used for building construction to a very limited extent. Steel beams and cast iron columns were used for inside supports of wooden joist and floors, while for outside walls self-supporting masonry construction was the common practice.

Fireproofing was hardly known ; elevator service was slow and uncertain ; electric lights only seldom used and steam heating of this class of buildings a luxury only afforded in isolated cases. To-day the modern building furnishes the most excellent service in all these lines, besides being supplied with hot water, ice water for drinking purposes, etc., etc.

With the advance in property values in the business districts of all large cities came the demand for buildings that

would pay a higher revenue, and inasmuch as the air was free, investors began to look for higher buildings, that is, buildings over 6 or 8 stories high. Hand in hand with this gradual increasing demand for higher buildings came the increased use of iron and steel in building construction. With the added height the risk from fire became greater and the demand for fireproof material for protection of the steel became very urgent. Brains and capital working hand in hand soon were able to cope with the demand.

As Mr. P. B. White, in his paper read before this Society, covered the ground in regard to fireproofing so thoroughly, further remarks from me on this subject would be superfluous.

With the advent of reliable fireproofing material there was nothing to hinder the architects and engineers in their efforts to supply the demand for high and safe buildings, so that we observe the results all around us, "sky-scrapers," buildings over 20 stories high, supported entirely on steel columns with steel girders and beams carrying the walls and floor; all steel being protected against the influence of fire by terra cotta covering, brick, concrete, etc. One of these modern buildings, as a whole, is an engineering undertaking of no small proportion. The success of such a building depends to a great extent on how the engineers engaged in planning both the structural and mechanical construction of these buildings have solved their problem.

The structural engineer is depended upon for stability of super-structure and foundations; the mechanical engineer for economical and successful working of the extensive mechanical plant.

When we stop to think that this development from the old to the new style of buildings has taken a period of less than 20 years, we may well ask ourselves what will the next 20 years disclose in this line.

Improvements have come so rapidly that it has been hard to follow them, and I predict that the next 20 years will show

great improvements over what we now consider the height of perfection.

We consider these modern buildings proof against fire, and they are to a certain extent, but so long as we employ any combustible material in their construction the term "fireproof" is only relative. Some day we shall probably construct of entirely fireproof material, not employing any wood. We shall find some protecting material for our steel which is not affected by heat and and water, and at the same time light and durable. We shall see improvements in our methods of heating, lighting, ventilating, plumbing, elevator service, etc., etc. We shall see a new architectural style developed; a style more adapted to steel construction than those now in vogue, and we shall see improved methods of building our foundations, and concrete will play a much more important part in the future than it has in the past.

THE UNION DEPOT.

As you are aware, the Pittsburg Union Station combines the features of a modern office building and a depot; the first story and basement being fitted for depot service, and the balance from the second story up arranged for office purposes.

The basement is reached by a drive-way from the west running through the basement with exit on a level with Liberty Street, on the north. The building proper is 137 feet x 225 feet long, fourteen stories high, including basement and attic, being 210 feet high from the level of Liberty Street to top of cornice.

On the west end of the building is the covered cab-stand, 128′-6″ square, on the north and south sides there are covered walks 18′-6″ wide running the entire length of the building. These walks have a roof of glass.

On the east side towards the train shed is a covered platform 60′ x 164′. In the basement on both sides of the driveway mentioned are the baggage, express and store rooms. The

first floor containing the general waiting room, lobbies, dining room, ladies and gentlemen's waiting rooms and toilet rooms, ticket office, special baggage rooms, barber shop, etc.

The general waiting room has an area of 10,400 square feet, being about 67 feet by 155 feet. This room has a sky-light roof over it at a level of third floor, and from this point up the space occupied by the waiting room on the first floor becomes an open air shaft.

The foundations are made entirely of concrete, resting on a gravel bed, which our test borings show to be 50 feet deep, and going down to the rock. Over this gravel bed we found an 8 foot thick layer composed of filling and rubbish, and between this layer and the gravel, a bed of clay. The upper layer contained debris from fire, a few coffins, remains of the old canal, etc. Most of the concrete foundations are made round, tapering off conically to the top. While some are square, all are proportioned to impose a load of four tons per square foot on the ground and sustain a load of twenty tons per foot on the concrete at bottom of shoe.

Specifications for concrete are one cement, two sand and four parts of broken stone.

The round form of piers was adopted on account of being easier to shore and more economical in construction than the square footings. Vulcanite cement was used and the concrete was of an excellent quality, as we found out later when we had occasion to cut into it.

The proportions above mentioned for concrete may be considered by some engineers somewhat rich, but considering the manner of practical making of concrete, it is a good fault to have a surplus amount of cement and mortar, in order that all voids in the broken stone shall be entirely filled.

Resting on the concrete footings is a large cast iron shoe under each column distributing the load over the top of the pier. This shoe was set on wedges and grouted from the center with cement and sand mixed in proportions of one to one.

CAB STAND.

The superstructure is of open hearth steel, the column being made of four 8 x 8 angles with web and side plates connected together in the outside and court spandrels by 36" deep plate girders. The floor beams and girders are all 15 inch beams, calculated to sustain the actual dead load, besides a live load figured in this case to be 70 pounds for upper floors and and 100 pounds for the first floor, per square foot of floors.

The roof over waiting room is supported by trusses from column to column and offered the fitting shop some very interesting features in the way of groins for arch penetration. The groins are made of tee irons and are such a shape that they cannot be drawn in two projections. The most interesting and novel feature in connection with this station building, from an engineering standpoint, is the steel construction of the cabstand, but as usual, this, as well as the rest of the construction, is hidden from view, and uninitiated get the impression that the cab-stand is a solid brick and terra cotta arch and dome construction; while in fact all of this work is supported on steel construction, as you will see from this photograph.

Four pairs of elliptical shaped arches, one pair for each of the four sides of the cab stands, support the large front arches. The corner pavillions are what they pretend to be: self-supporting brick and terra cotta construction. The inside arch of each of these pairs supports the center dome of the cabstand, the inside surface of which on the four diagonal corners form a hemisphere. This hemisphere is cut off on the four sides by the above mentioned trusses, whose form corresponds to the intersection of the vertical plan with the dome on line with this truss.

The whole dome is made of ribs and rings, as usual for dome construction, but in this case some of these ribs terminate higher than others, and connect to the three hinged arches.

The terra cotta had to have special supports at certain intervals to suit the size of the terra cotta blocks. This makes a very complex net work of tees and angles. It is one of the most complicated pieces of structural work that I have ever come in contact with.

The arches are regular three hinged arch construction. Both the dome and the arches are simple enough in themselves, from an engineering standpoint, but when the continuity of the dome is broken, as is here the case, a few intricate points come up for consideration. The girders along the extreme east line of the covered train-shed platform are interesting, in so far as their construction is such that by accident any *one* of the columns supporting this line of girders can be removed from under it without endangering the safety of the roof, which they support.

Mr. Worthington, in his recent paper read before this Society on steel frame work for high buildings, has dealt in a general way with the steel construction of high buildings, and I certainly agree with him in what he says in regard to wind bracing; namely, that frame work shall lend stiffness and stability to the masonry, instead of vice versa. I therefore adopted the deep spandrel girders in all my work, adding stiffness and rigidity to the building without of necessity increasing the weight or cost of the steel.

I always consider the ends or sides of the building, whichever it may be, according to the direction of the wind, acting as abuttments. The wind load from intermediate columns being transferred through the floor system, floor by floor to the sides and ends. Of course the inside columns add some to the stiffness, but I take them very little into consideration, as the members connecting to inside columns are shallow.

There is no doubt that the weight (mass) of a building in itself is an element of stability ; otherwise some of these buildings constructed without regard to wind bracing would not stand up, but the fact that they do stand up is, in my opinion,

no excuse for omitting proper precaution against the action of even unexpected strains, especially as it can be done at a very small extra expense. In buildings where this is not done there is bound to be considerable vibration, which, in time, will injure the building.

Where no special ordinances exist specifying loads, it is my custom to figure floor beams of office buildings for a live load of 70 pounds per square foot, in addition to the actual dead load; for girders 56 pounds, or about 80 per cent., and for columns 42 pounds, or 60 per cent. of the live load for the floor beams per square foot of floor, in addition to the actual dead load, assuming that the entire floor contingent to any given girder will not be loaded to its maximum at any given time, the same argument being used to a higher degree in case of the columns.

In proportioning column foundation I consider the actual dead loads, and in addition thereto a live load of 10 pounds per square foot of all floors, all of which figures are subject to modifications in special cases and under special conditions.

The building has seven hydraulic passenger elevators, four on west and three on east end on Liberty Street side, and in addition to this a direct hydraulic lift for baggage between baggage rooms in first floor and basement.

The floor arches between beams are all regular terra cotta construction. All corridor partitions are built of tile while many of the partitions between the offices are of expanded metal and plaster two inches thick.

Other novel features in this building are pneumatic tube systems connecting all the floors from 2nd to 12th inclusive, with receiving and sending stations at each floor, and ice water circulating system furnishing ice water for offices and first floor waiting room.

From an architectural standpoint, a building like this serving two distinct purposes, namely, depot and office building, is a rather difficult problem It is hardly possible to give

wainscoting, ornamented and decorated plaster ceilings. All doors and interior trim is quarter-sawed oak throughout. The entire first floor is finished in white Italian marble with Belgian black marble forming geometrical patterns.

CHAIRMAN—Gentlemen, will you discuss this paper?

A MEMBER—I notice that Mr. Giaver used four-angles for his columns and single web. The engineer has to choose either this section or a section made up of channel plates, Z-bars or special sections, but I never could see why you should use anything but four-angles and webs as they are used in this case. I don't see any advantage in using any other section. I would like to ask why he chose this?

MR. GIAVER—In choosing a section like that, there are several advantages, one thing you can connect them on all four sides during the construction before the building is completed. If you choose the box section you can never get at it. You don't know whether that column has been filled with water during the erection of the building unless you make special arrangement to take it out. I have not found any objecton to these columns and I have found objection to others. I use Z-bars for low buildings, but when you come to a load of two hundred thousand pounds you have to put plates on them. That is my reason for using the other. Besides, the bridge companies like them better. (Laughter.)

A MEMBER—The four-angle column is the more plausible section. With the four-angle you can start with the smallest size at the top and use the larger size as you go down. Of course the small size Z-bar is heavier than the other.

MR. JOHNSTON—I would like to enforce what Mr. Giaver has said about the box column filling with water during construction. I had one case in my experience which caused me to take a hasty ride of about two hundred miles, thinking the foundation was settling and the whole thing was going to the dogs. When I investigated the matter I found the column had filled with water, and as it was winter time the freezing

such a building an architectural expression which will suggest its dual character and usefulness. Either the depot or the office building must prevail in the main design, and in this case the character of office building has been maintained for the main building.

The cab-stand, with its large outer arches and center dome and the grand approach, have been made the features of this structure, which at once suggests a monumental entrance to the railroad station. After entering the lobbies and main waiting room on first floor, all impressions of the office building are forgotten. It is a station for a big railroad corporation.

The entire structure has a modern, monumental, architectural treatment. Brick and terra cotta with a granite base forming the outside finish; the cab-stand being finished almost entirely in terra cotta. The interior walls of vestibules and waiting rooms on first floor are finished in sand-blasted glazed terra cotta, while the ceilings are decorated ornamental plastering. Glazed terra cotta suggested itself and was adopted for the interior walls of the main waiting room and vestibules on account of its cleanliness, as well as general effect.

The roof over the waiting room being mostly all glass, gives abundant light from the large light-shaft above, which is lined with enameled brick in order to reflect as much light as possible.

On the office floors the offices are all located towards the outside of the building, with corridor along the inside court walls, this arrangement insuring in all cases a large amount of light and air for all the offices. The offices, as well as the corridors, are well ventilated and heated according to the latest and most improved methods.

All corridors have marble floors and base. The two stairs running up through the entire building are made with iron stringers and risers and marble treads. All the offices have maple floors, decorated walls and ceilings, except special offices and committee room, which have oak floors and oak

wainscoting, ornamented and decorated plaster ceilings. All doors and interior trim is quarter-sawed oak throughout. The entire first floor is finished in white Italian marble with Belgian black marble forming geometrical patterns.

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MR. GIAVER—In choosing a section like that, there are several advantages, one thing you can connect them on all four sides during the construction before the building is completed. If you choose the box section you can never get at it. You don't know whether that column has been filled with water during the erection of the building unless you make special arrangement to take it out. I have not found any objecton to these columns and I have found objection to others. I use Z-bars for low buildings, but when you come to a load of two hundred thousand pounds you have to put plates on them. That is my reason for using the other. Besides, the bridge companies like them better. (Laughter.)

A MEMBER—The four-angle column is the more plausible section. With the four-angle you can start with the smallest size at the top and use the larger size as you go down. Of course the small size Z-bar is heavier than the other.

MR. JOHNSTON—I would like to enforce what Mr. Giaver has said about the box column filling with water during construction. I had one case in my experience which caused me to take a hasty ride of about two hundred miles, thinking the foundation was settling and the whole thing was going to the dogs. When I investigated the matter I found the column had filled with water, and as it was winter time the freezing

and swelling burst the wall, which caused the excitement and disturbances. We drilled a hole in and let out more than a barrel of water.

MR. RIDINGER—Mr. President, Mr. Giaver spoke of fire proofing. I would like to know his views on re-enforced concrete for fire-proofing.

Mr. GIAVER—I want to say that I am not an expert concrete man. There may be some other in this assembly. I have looked into the matter and think re-enforced concrete for certain classes of work has come to stay. It is simply a matter of getting it cheap enough. In regard to floor arches, if anybody could find a fire proofing system to suit arched floors which is strong and light at the same time, there is a great field for it. I find that when you come to supplant the old arch system it is very hard to find a material with which you can do it cheaply. I am up against the architects right along you know. They ask me how much steel it will take to construct this building, and they want you to cut that in two; now that is the incentive, I have to try something that is better or lighter. I have just finished the design of the First National Bank building. If I could save ten pounds to the foot on the floor load the saving would be 0000000000 in that building. In fire-proofing flat ceilings that means that we have to have two plates and a level space between, and you can't get below forty to save your neck. That is the weight of the sixteen inch arch. We have a surplus amount of strength in this arch, and if we can find something to make it strong and weigh less, we are on the right road. There may be some material that will do it.

MR. KENNEDY—I would like to ask if there is any one here who knows why the general size of the Union station was made suitable for a small town like Cleveland or Buffalo instead of a city like Pittsburgh, which grew away from it while it was being built? There may have been some geographical limitation, or it may be due to the cab stand (laughter).

MR. GIAVER—In Mr. Clarks' talk you see that the tracks on the south side and the north side have limited the width of the station. We had to have the cab stand ; that is the only thing that makes the station, don't you know that?

MR. CLARK—I give the size of the north, south and east but didn't say it was limited on the west.

MR. WHITED—Mr. President, I might possibly suggest one reason for that. If anybody ever went to travel on the train with an old lady and it was only a half a mile from the ticket office to the train he would wish the cab stand was at the other end of the station instead of in the front.

CHAIRMAN—The next is a paper entitled "The Power Plant, the Power House, Boilers, Engines, Generators, Switch Boards, Air Compressors, Refrigerating Plant, Elevators," Etc., by Mr. D. B. Kinch, Electrician, Union Station, P. R. R., Pittsburg, Penna.

MR. KINCH—It was my original intention to cover the mechanical equipment of the station, but I have eliminated the station and give the power plant only. At some future time I would be glad to go into detail of the station but I don't want to consume any more time than is necessary as there are so many papers this evening.

THE POWER PLANT OF THE NEW UNION STATION.

BY MR. D. B. KINCH.

The power plant of the New Union Station is a modernized plant in every particular, both as to the constructive and economic details. Encompassed in the building directly south of the Station, a multiplicity of machinery occupies every available inch of space, somewhat more crowded than it should be in an ideal plant. The space occupied by the building, 55′ x 420′, contains a varied machinery, little thought of by the thousands of people daily passing within a few feet. The centralizing, in an isolated building, of all of the generating machinery for a terminal station and yards, is an ideal condition that cannot always be adhered to, as is the result in this instance. Here, this is due to the exceptional location selected for the plant. As the Union Station is a consumer of perhaps 75% of the output of the plant, the location is certainly ideal. From an operating viewpoint, it could not be better; but, notwithstanding this simplifying condition, the engineering details that were constantly arising required careful plotting and planning and re-plotting and re-planning, little of which is shown by the completed plant.

The power plant of a large terminal is wholly and in reality the living portion of it, and to keep it breathing regularly is of no small concern day and night. A total shut-down is the most dreaded thing that can happen to those in charge, and is the one thing guarded against so closely. The slightest appearance of a rupture by signs we all know so well, are battled forthwith, and immediately. For, to the terminal and its yards, it is the living thing, and is in itself the one great potentiality. The movement of the trains, numbering hundreds daily, depends wholly upon the air compressors for their operating power, and generated here is the current for the storage battery controlling these movements.

The heating and ventilation of the Station, the elevators for both the offices and baggage service, the lighting of the building and yards, the filtering and refrigerating of the drinking water, the building service water, and pressure for fire mains, the entire telegraphic service, etc., etc., are all a vital part of the whole; and the failure of one portion, for even a limited time, means a serious handicap and confusion.

Duplicated as to the most vital points, unusual provisions and precautions were provided in this installation. No false economies were made or asked to be effected at the sacrifice of the best practice. Knowing we have a very complete plant for its various uses, we also know that as to some constructive details, we will be open to the usual criticism that new plants always are subjected to, looked at from the various viewpoints of each engineer for himself. However, for these criticisms we can only offer one answer, and that is that the best practices with the local conditions governed; and that these local conditions were wholly the deciding elements, and were always worked up to, probably in some instances at a sacrifice to the ideal.

The engine and generator equipment comprises four marine type Westinghouse compound engines. These engines are of the standard marine type design. The high pressure cylinder being 17 inches in diameter, the low pressure cylinder 27 inches, with a 24 inch stroke. They are equipped with a Right's governor and have a speed of 200 R. P. M. The high pressure cylinder is equipped with a piston valve, double ported, and the low pressure with a slide valve, double ported. The engines are direct connected, to 350 K. W., 220 volts, two phase, alternating current dynamos, of the Westinghouse standard type. One engine driven and one motor driven direct current dynamos each of 37½ K. W. capacity, serve as exciters. These exciters also furnish direct current for a number of small motors, used at various points throughout the building on special apparatus for which alternating current

motors are not, as yet, provided by the manufacturers in connection with their apparatus.

Current for the storage battery used in connection with the switch and signal installation is also provided from the exciters. These direct current machines also furnish the primary current for 14 Crocker-Wheeler dynamotors, used exclusively for the telegraphic service. The output of these numerous little machines varies from 8 volts on "locals" to 360 volts for duplex and quadruplex service. Battery current for telegraphic purposes is entirely supplanted by the installation of these small sets.

The switch-board panels are of blue Vermont marble, and the board is composed of 13 lower and 9 upper panels, each equipped with main and auxiliary bus bars. Stairways at either end of the board, give free access to the gallery around the upper panels.

The lower panels are used for the generating and high tension work and the upper panels for the distribution.

It is our intention to run the alternators in parallel, and to this end the syncronyzing apparatus is one of the board features.

Step-up transformers at a ratio of 10 to 1 are installed to furnish lighting and power circuits to outlying districts.

Ample circuits for series A. C. arc lamps are provided, and for this work a combination jack and plug board is used. All transformers, as well as rheostats, are placed in the basement directly underneath the switch board, thus clearing the back of switch board to an unusual degree. The electrical equipment occupies the entire south side of the engine room, whilst along the north side are located the air compressors, hydraulic pumps, high pressure pumps, small air compressor for thermostatic heat control in the office building, a Scotch yoke air compressor, etc.

The main pumping engine for hydraulic elevators is of the Riedler type, being fitted with mechanically operated valves.

It has duplex single acting outside packed plungers, 9½ in. in diameter and 24 in. stroke, steam cylinders 13 in. and 23 in. in diameter with 24 in. stroke. This pump, having a capacity of 1,400 U. S. gallons per minute, against a pressure of 200 lbs. to the square inch, when running at about 96 R. P. M. with a steam pressure at throttle of 150 lbs. The main feature in the design of this pump was to cut down the floor space to the smallest possible area. For this reason the valve gear was put on the outside of the steam cylinders, in order to get the cylinders close together and do away with the necessity of a passage between the gears, which would have materially widened the engine. The engine frames were made of the double bearing type, with four part adjustable boxes for all bearing. The entire water and steam end of pump is mounted on a substantial bed plate of box section, insuring alignment and in order to further economize the floor space, the pump end was made of the single acting type, as this would cut down the space required about one-half of that necessary for the double acting pump.

The distinctive feature of this pumping engine is the mechanically operated valves. As the pump is single acting, it was necessary to provide a by-pass so as to enable the pump to run without delivering water when the pressure had passed a certain point. The by-pass valve is operated by means of an air cylinder, which also operates an auxiliary throttle; the steam for running the pump being taken through a small by-pass on the side of this throttle, this by-pass having a valve in it, so that the amount of steam fed to the pump can be adjusted that the pump will not run more than 30 R. P. M. when running on the by-pass.

The air cylinder for operating water by-pass valve and throttle is controlled by means of a pilot valve operated by an auxiliary governor, this governor only coming into effect when the speed of the engine has dropped to between 20 and 25 R. P. M. All of the working parts of governor are central, so

that friction is entirely elimated; as auxiliary pumps for elevator service we have installed two simple direct acting Worthington pumps of 750 gallons each. These are also used for the night run. The elevator equipment comprises seven high speed elevators, to travel from train floor to top floor, a distance of 190 ft., and eight direct lift elevators, used for baggage and express service.

For the furnishing of air to the signals and switches as well as for car testing and car cleaning purposes two cross compound vertical Reidler express type compressors are used. Sizes of air cylinders are 14″ x 24″ in diameter with 24″ stroke driven by a vertical cross compound, non-condensing Corliss steam engine with cylinders 13″ x 23″ in diameter and 24″ stroke. Each compressor having a capacity of 1500 cubic feet of free air, not piston displacement, to a maximum pressure of 100 lbs., when running at a speed of 134 R. P. M. The air cylinders are mounted above the steam cylinders. Both air cylinders and heads are water jacketed. The air suction and delivery valves are placed in the heads; the suction valves being of the semi-rotative type operated by means of a wrist plate, driven from an eccentric in the same manner as the steam gear. An inter-cooler and an after cooler are provided. The inter-cooler having a volume of about six times the volume of the low pressure cylinder, the air being cooled by means of water passing through the tubes. After the air has been delivered from the high pressure cylinder it is passed through the after cooler so as so remove as far as possible all moisture. The is then delivered to storage tanks located in what is known as air the air intake building. This is a separate building of small dimensions directly west of the engine room, and is equipped with storage tanks for air delivery to various points and also with appliances for thoroughly cleansing the air before it is delivered to the suction pipe. A 15 ton electric crane travels the entire length of the engine room, thus assuring valuable aid in case of need.

The boiler room is equipped with Babcock Wilcox boilers. These boilers are of standard type and are all of forged steel construction, built to carry a working pressure of 200 lbs. The boilers as installed comprise six boilers in three batteries, each unit 300 H. P. an aggregate of 1800 H. P., space being left for an additional battery for future increase. The boilers are equipped complete with Roney stokers and installed in the boiler room is a Hunt coal and ashes conveyor. Hoppers of 50,000 lbs. coal capacity are located over each battery of boilers and cams are arranged at convenient points along hoppers for dumping the buckets. The conveyor movement is made by a steam engine located in what is known as the annex. The conveyor extends along the top of coal hoppers and passing down the side of west battery runs the along basement floor and at this point receives the ashes from the ash hoppers under each boiler, and the buckets of the conveyor receive these ashes through an automatic filler located directly under hoppers. The ashes are stored in a large hopper located in the second story of the annex from which chutes are arranged, and the ashes are dumped into cars which but a few moments before contained the coal.

A coal crusher is installed at the lower end of the coal hopper and only used when lump coal is delivered.

Two Cochrane feed water heaters each of 1500 H. P. capacity are employed in boiler room, and feed water is delivered to the boilers at a temperature of 200 degrees Fahrenheit. All feed water piping to the boilers is of brass and in duplicate.

The chimney is located in the middle of the boiler room and south of the center line. The smoke flues enter chimney on basement level. Suitable dampers under automatic contro- are installed. The chimney is of the well known Custodius perforated radial brick, and the actual height without base 240 feet with a base of 13 ft. 6 in. high. The diameter of chimney is 9 feet. An 18″ exhaust pipe extends the whole length of the chimney and extends above at top about 6′. This pipe will

take care of all the steam exhausted during the warmer months. During the colder months the exhausted steam will be employed in heating the office building. The total weight of chimney, including the exhaust pipe, is about 2,600,000 lbs.

Special attention was devoted to the steam piping system, the view point always being that only partial shut down would result in the case of ordinary repairs or accidents. The piping is all extra heavy, with screwed flanged fittings. Two headers extend along the entire length of boiler room, along the rear of the boilers and about 8′ above them. Into each one of these headers, is a main from each boiler. This practically duplicates the piping in the boiler room. At the partition wall between the boiler and engine rooms the mains drop to the basement and loop around the engine room. The main steam line runs in about a 4′ space between the foundations of engines and the wall of building. At each point where a connection is made for engines, valves are placed on either side of this connection in the main line. Thus the connection to any engine can be cut off from the main steam line without interfering with the supply to other points. The exhaust line extends along the center of basement and connects to exhaust line in stack and also to a large distributing tank to which the building heating system is connected. A back pressure valve is located on exhaust line leading into the stack. At the west end of the engine room the exhaust line leads up to the roof, connected to exhaust heads. On this line, also, there are back pressure valves.

The refrigerating and drinking water plant is located at the partition wall between the engine and boiler rooms on the boiler room side, and is of the Carbondale Machine Co's. construction. The duty performed consists of refrigeration for two refrigerators for kitchen on top floor, containing approximately 1,000 cubic feet, also refrigerating for main restaurant boxes containing about 4,000 cubic feet, the connecting mains aggregating 1,200′. The filtering and cooling

of the drinking water supply is for about 125 fountains, located in the offices and waiting rooms. The amount of water cooled is about 750 gallons per hour, with a range of 45 degrees Fahrenheit, i. e. from 80 degrees on the intake to 35 degrees to delivery mains. The delivery mains connect with sets of risers in the basement, from which lead the horizontal supply lines to each of the floors connecting to the office outlets, by means of an additional faucet at each washstand. The risers and mains aggregate about 11,000 lineal feet of pipe in supply and return mains. The temperature of the water at the drinking fountains is about 41 or 42 degrees. The method of circulation used ensures equal temperatures at all points, freedom from air in pipes and a continuous supply at all faucets. Stop or regulating cocks are placed at all fountain loops, to provide against excessive pressures due to the height of risers. The pressure at the water circulating pump in the basement of the power plant, a 9″ x 5½″ x 12″ duplex, is about 95 lbs. The steam required is about 32 lbs. per ton refrigerating effect per hour. The refrigerating machine is of the Carbondale company's standard Pontifex-Hendreck absorption pattern of 40 tons capacity, and consists of the generator, analyzer, exchanger, absorber, condenser and brine cooler, with duplicate direct acting single ammonia pumps and duplicate duplex brine circulating pumps. The refrigerant used is fused calcium chloride of 1,250 sp. gr. This substance is circulated through coils in refrigerators, and very low temperatures are possible. The location of refrigerating machinery in power house being essential, and the limited available space necessitated the placing of this apparatus in a space of about 8′ x 30′, and on three different levels. The machine proper standing on a platform of steel construction 200 feet square, 12′ above the power house floor. The cooling and brine storage tanks, with ammonia pump, on the main floor directly underneath, and the water circulating pump and filters below in the basement.

For the convenience of employes, lockers, washrooms, shower baths, etc., are to be equipped and located in the east end of the basement.

CHAIRMAN—Gentlemen, the paper is open for discussion.

A MEMBER—I would like to ask Mr. Kinch what kind of water is used?

MR. KINCH—We take it right out of the city mains and filter with a sand filter.

A MEMBER—What do you do with the condensation water?

MR. KINCH—It goes back into the tank and from there it is pumped up into the water heaters.

CHAIRMAN—Mr. Kinch, is your filtration under pressure?

MR. KINCH—Yes, it is under city pressure. That varies considerably, from thirty-five pounds on week days up to sixty pounds on Sundays.

CHAIRMAN—Prof. Kintner, have you anything to say?

PROF. KINTNER—I have nothing to offer at all. I was just admiring the paper. Any one of the subjects could be made the subject of a paper. Mr. Kinch has covered a great deal of ground in very concise statements. I liked the papers very much.

MR. KNOWLES—One thing which interested me particularly was in regard to the stokers used. Was there any reason why that particular stoker was chosen?

MR. KINCH—We have no other particular reason for using this stoker than that we have never experimented in regard to the stoker business very much. We have always found the stoker which we have installed there to be very satisfactory. We did not have any desire to do any experimenting, and we were perfectly satisfied with the stoker because it had given satisfaction at other points.

CHAIRMAN—If there is no other discussion, we have another paper on our program entitled "The Electro-Pneumatic Interlocking Switch and Signal System". Considerations which lead to a decision in favor of the system adopted. A

brief discussion of the factors constituting an ideal system. Description of system. The electrical energy required to operate the controlling devices, and the pneumatic energy required to operate the switches and signals. Extent of the system; comparisons with other existing plants of like character. Some figures concerning the number of lever and train movements executed in a given time," by Mr. J. G. Schreuder, Assistant General Manager and Chief Engineer of The Union Switch & Signal Co., Swissvale, Penna.

A DESCRIPTION OF THE WESTINGHOUSE ELECTRO-PNEUMATIC INTERLOCK SWITCH AND SIGNAL SYSTEM INSTALLED IN THE YARDS OF THE PENNSYLVANIA UNION STATION, PITTSBURG, PENNA., BY THE UNION SWITCH AND SIGNAL COMPANY.

BY MR. J. G. SCHREUDER.

It is seldom that a system of interlocking switches and signals for any given place is determined in quicker fashion, and with as little waste of time and energy, as was that now installed in the yards of the Union Station.

This quick decision, or rather absence of discussion, was distinctly the result of the long and thorough experience had with this system, so that the "Electro-Pneumatic" had come to be regarded as so pre-eminently fitted for the requirements, that a consideration of any other would have amounted to little more than an empty form. No one would now talk seriously of replacing the Westinghouse Air Brake with any other. Generally stated, the conditions to be met in the manipulation of switches, especially the modern heavy section of rail and rigid construction, as well as the operation of signals giving right of way over them, call for a motor which combines the elements of great power, quick response, little inertia, durability, simplicity and compactness.

Power, because of the heavy rail, rigid construction and wide range of resistance, due to other causes, which a switch may offer to its movement.

Quick response, so that no time may be lost, from a state of rest, to that of full speed, when the actuating force is applied.

Small amount of inertia, a necessary element to secure quick response, avoidance of damage to any of the parts, should the switch in its movement meet an obstruction, or in coming to rest at the end of it.

Durability and simplicity, for obvious reasons, and compactness because the space available is often much restricted.

A little reflection will show that a cylinder, whose double acting piston is operated by air at from 75 to 100 pounds pressure per square inch, is the only motor fulfilling these conditions.

The actuating or controlling force and its means of transmission from a central point, to the switch or signal operated, constitutes another important element in an ideal system.

This force must, first of all, be instantaneous in action, its transmission accomplished without any mechanical movement, the transmitting medium must be small and occupy but little space, and the strength of its confining walls of as low requirements as possible.

An electric current of low voltage and low amperage, it is almost needless to say, is the only known method of accomplishing these results.

It is, of course, instantaneous in action, and the distance of a switch or signal from the central point of operation is of no consequence.

There is no mechanical movement of any solid or fluid matter in its transmission, the conductor may be small on account of the light current required, and the insulation, due to the very low voltage, permits of the wires being placed in any convenient location, buried under the ground in ordinary wood trucking, or it may be placed anywhere in locations safest from mechanical injury, and where space is most readily available.

Last, but of no less importance in an ideal system is the interlocking machine, whereby not only are all switches and signals operated from a central point, but interlocking between them accomplished. Such a machine should occupy the least

possible amount of space, and as far as possible, call for no special structural features in the building or tower in which it is placed; it should operate the maximum number of switches and signals with the minimum number of operating levers, and the manipulation of such levers should be simplified where possible, by giving some fixed relation in the matter of position between the lever and the direction of the train movement governed. All of its parts should be easy of access, so that inspection and care may be readily and quickly accomplished.

That part of it known as the "interlocking" or "locking" and from which, by the way, all interlocking devices derive their generical name, should be of such design that no limitations exist as to extensions. In some systems the locking may be made satisfactory in a small plant, but the larger the plant becomes, the more impracticable the locking.

By interlocking is meant such an arrangement of interference, either mechanical or electrical, between the levers operating switches and signals, that a signal cannot be cleared giving right of way over a route until all switches within it are in such position that it is proper for a train to proceed over it. The act of clearing the signal, conversely, locks all levers having to do with the route, so that the position of the switches cannot be changed while a signal is displayed giving right of way over them. As a further result, it follows that no train movement could, at the same time, be made over any other route which conflicts with the one previously given. This brings us to the consideration of a feature in which the Electro-pneumatic system is unrivalled. It is evident that if a number of routes are conflicting, or in other words, lead into one which is common to all, the respective signals governing such routes may be operated by one lever, since but one of these can be used at one time.

All such signals governing traffic in one direction may therefore be operated by this one lever, it being thrown, let us

say, from the center position to the right. This same signal lever by being thrown from the center to the left position, may operate signals for train movements in the opposite direction over all routes which conflict with the above. We may now arrive at what is practically a formula for determining the number of signal levers which will be required for any given plant, i. e., equal to the number of non-conflicting train movements which can be made simultaneously.

Each switch lever may operate as many pairs of switch points as are required, or may have, at all times like relative positions. Thus it frequently occurs in the operation of double slip switches, having movable point frogs, that one lever operates eight pairs of points, together with the related detector bars and locks.

The position of the switch operating levers are known as "normal" and "reversed," and those of the signal levers as "normal" (the center position) and "right and left." The former are usually the top row and the latter the bottom, although either can be adapted to perform the functions of the other, should conditions make it desirable to do so. Each lever rotates a shaft, which has secured to it certain mechanical connections which, by interference or non-interference with like mechanical connections with other levers, accomplishes the interlocking feature explained above.

On extensions of these shafts are secured suitable contact parts which control the electric current for operating the switches and signals, and secured to a still further extension are mechanically interfering parts which are released by the action of the armatures of electric magnets. The current which actuates those for the switch levers—of which there are two—one for the normal and the other for the reversed position, are controlled by contacts operated by the switch, and indicate whether the switch has responded properly to the preliminary movement of the controlling lever in the machine. If it has not, the indication magnet does not release the lever,

thus preventing a completion of its movement, which in turn prevents, by mechanical interference in the locking, the movement of the signal lever giving right of way over the route in which the switch is located.

The current which actuates the magnet connected with the signal lever is controlled by contacts operated by the signal, thus insuring the proper display of a danger signal before a route, after having been set up for a train movement, can be changed.

The means for controlling or operating switches and signals are purely electrical, as well as are the means, as explained above, for detecting the correct response to the movement of their respective operating levers. Upon the shaft of each switch lever are arranged suitable contact parts for controlling the switch operating circuits. In like manner each signal lever, the signal or signals assigned to it. If more than one signal is controlled by the movement of the signal lever from the center or normal position to the right, that one which corresponds to the correct position of the switches constituting a route, is automatically selected by contacts on the shaft of those switch levers involved in the route,

The same is true for similar conditions in the movement of the same signal lever from the center of the left position.

This it will be seen is a very attractive feature of the system, in that a leverman has only to operate those switch levers involved in the route desired, and lastly the signal lever. Should this lever, however control a number of signals, this fact is of no concern to the leverman, since as explained above, only that signal which corresponds to the route will respond.

All semaphore signals as used in interlocking work are divided into two general types. The "High" signal, used chiefly for high speed routes, because they are more conspicuous, and form a desirable contrast to the "Dwarf" signal, which is used for inferior train movements, and possess the advantage, on account of their form, of being placed between

tracks, whereas the "High" signal, in order to have an equally advantageous location with reference to the track governed, must be placed on an overhead bridge.

Each signal is equipped with a single acting cylinder, by means of which the compressed air moves it to the clear position, and in so doing not only overcomes the friction of its moving part, but stores up potential energy in the form of gravity or a compressed spring, which is available to restore the signal to the danger position when air pressure is released.

This arrangement, while simplifying construction, is a feature of a vital and generally accepted principal in all signalling appliances, which, it may be well to say here, is that the display of a signal which gives right of way for a train movement should be the result of the proper active effect of the energy (in whatever form or forms) which is employed, so that a failure of any part would not cause a situation of danger. This is, of course, a sort of corollary to the proposition that the most reliable force available, is the one which should be used to effect the display of a danger or "stop" signal, which without doubt, is gravity.

In this system, as previously explained, an electric lock on each signal lever in the machine insures, because of the operation of the lock by the signal itself, the display of a danger signal before change of route can be effected. As it is desirable to use a spring instead of gravity to restore the dwarf signal to the danger position, this device makes it possible to do so with safety.

The signal is cleared by air being admitted to the cylinder through a pin valve, which is forced open by the armature of a magnet controlled by the machine. When this magnet is de-energized, the armature is released, the admission port closed, the exhaust port opened and the signal brought to the danger position by spring or gravity. One conductor is run from the controlling lever of the machine to each signal operated, known as the signal controlling wire, and one conductor

from the lock magnet of each signal lever is run, in series, through the circuit breakers of all signals controlled by that lever.

All signals, of whatever type, and there a great many indeed, will, in the manner of displaying information, come under the general headings of color, form or position, with numerous sub-divisions of each.

Those used with the system under discussion are position for daylight and color for night. The former consists of an arm about five feet long by an average width of nine inches, extending horizontally from a mast or pole, when in danger position, and inclined at an angle of about sixty degrees below the horizontal when in the clear position.

The latter, that of color for the night signal is red for the danger and white for the clear signal. An extension of the device which carries the day signal is made to carry colored glasss which pass in front of a source of light, thus giving the desired information.

In the operation of a switch, the only features which distinguish it from that of a signal are in the fact that the switch cylinder, is double acting, thus requiring a duplication of parts, and further, that instead of the pin valve admitting air directly to the cylinder, it actuates a small piston, one for each position of the switch, which in turn operates an ordinary D valve, controlling the air to the main cylinder. This relaying feature is desirable on account of the increased port openings required by the switch cylinders.

The position of the D valve is further made secure against accidental movement by a lock, which is released by the action of an electro magnet controlled by a contact operated by the switch lever in the machine.

The three conductors necessary to accomplish the manipulation of switch mechanisms, together with the two necessary for the operation of the indications previously explained, constitute the five which are run from each switch lever in the

machine to the switch or switches operated by it on the ground. In cases where one lever operaters six or eight pairs of points with the locks and detector bars, it will be seen that the connection between the lever and the mechanism operated is comparatively insignificant.

The dimensions of the various cylinders employed are in approximate proportion to the work required of each, in order that all may use a common pressure, which in this case is 100 pounds per square inch.

They are as follows :

For	Diameter	Stroke	Piston Area	Vol. of Cylinder
Dwarf signals.................	3 in.	2 in	7.07 Sq. in.	14.14 Cu. in.
High signals.	3 in.	4½ in.	7.07 Sq. in.	31.81 Cu. in.
Single Switch.................	6 in.	8 in.	28.27 Sq. in.	226.16 Cu. in.
Double slip end, no frogs.	6½ in.	8 in.	33.18 Sq. in.	265.44 Cu. in.
Double slip end, with frogs......................	7½ in.	8 in.	44.18 Sq. in.	353.44 Cu. in.

The amount of power, in the form of compressed air, necessary to operate any given plant, is necessarily a very uncertain quantity. About the only known factors are the number and dimensions of the operating cylinders and the pressure required.

The unknowns are the number of operations of each size of cylinder in a given time, the extent of leaks which will be allowed to exist in the maintenance, the probable changes or extensions of the plant, leaks or other derangement within the compressor which may develop due to one cause or another, and the improbability of discovery and correction under ordinary conditions, unless they become very pronounced, and the still greater uncertainty as to what extent air may be used for other purposes about the terminal.

Of course the latter is an outside consideration, but the ability to meet such demands largely increases the utility of such a plant, especially when the pressure carried makes it suitable for other purposes.

Had we supplied compressors for furnishing air for the interlocking system only, the decision would probably have

for the system amounts to less than eight ampheres at twelve volts, or less than 100 watts, not as much electrical energy as is consumed by two ordinary sixteen candle power incandescent lamps.

This good and somewhat surprising showing is the result of many years of painstaking investigation and development.

Current for charging is taken from the light circuit, through resistance lamps.

In speaking of the extent or size of a terminal system or interlocking plant, the mere recital of the number of switches and signals operated does not always convey a satisfying impression, unless accompanied by comparative statements concerning similar plants elsewhere.

The following tabulated outline may be of interest, especially in connection with the plants at Boston and St. Louis, each of which, in its day, was larger than any interlocking system previously installed.

In the number of switches operated, it will be seen that in the Pittsburg Yard there are nearly as many as in the Boston and Maine Terminal, the Boston Southern Terminal and the St. Louis Terminal combined. Only those switches in the Terminal yard proper are counted in any case, nor does it include those for the suburban loop tracks in the basement of the Boston Southern Terminal, not yet in service.

The Pittsburg plant does not operate as many signals in proportion to the number of switches operated as do others, chiefly because the conditions do not call for the various cautionary and special signals ordinarily used. The machine at 15th street has the distinction of operating more switches than is done from any other one point in the world.

In all machines, the locking is arranged to permit of a signal being given for every route made possible by the track arrangement. That at 21st street is probably the most complicated of any ever attempted.

Most of the signals govern traffic over many track ar-

rangements, as for instance, signal 22R, which has 52 routes.

Further than this, the elaborate scheme of tracks permit of many different routes by which a movement can be made from one given point to another. Thus there is a case in which 12 exist within half the length of the interlocking at 21st street, any one of which may be made in one continuous train movement.

Location of Tower in Pittsburg Terminal, P. R. R.	Double Slip Switches with Movable Frogs	Single Slip Switches with Movable Frogs	Single Switches	Total Equivalent in Single Switches	High and Dwarf Signals	Number of Levers in Machine	Current Discharge (12 Volts) Amp.	Mechanical Levers Necessary to do the same work
21st Street	32	....	27	219	61	119	3.3	288
15th Street	39	....	23	267	83	131	3.6	344
Washington St	3	....	10	28	14	23	.5	52
11th & Liberty St	1	1	9	19	9	15	.4	34
TOTAL	75	1	69	523	167	288	7.8	718
St. Louis Terminal	....	....	....	134	....	131	....	....
B'stn Maine Temr.	....	....	....	191	....	119	....	....
" Southern "	....	....	....	230	....	143	....	....
TOTAL	....	....	....	555	....	393	....	....

Located at advantageous points, some distance away from, but controlled by each tower, are pneumatic whistles, the air to which is controlled electrically. The purpose of these whistles is to enable the towerman, to give timely warning to trainmen, who, on account of in-attention or other cause, do not heed the information given by the signal, thus avoiding delays, if not more serious results.

Another feature which may be of interest as showing the flexibility of this system is the control of the signal governing west bound train movements through the Panhandle tunnel. This is known as a slotted signal and is controlled very simply by the pneumatic tower at Washington street, the track circuit in the tunnel and by the mechanical tower at Fourth avenue. The clearing of this signal requires an unoccupied track through the tunnel together with the co-operation of each of the towers mentioned.

Still another is that of locking between towers, by which it is impossible to clear simultaneously, by adjacent towers, the signals governing train movements in opposite directions over given tracks extending between them. This is done electrically between certain signal levers in the respective towers, which levers may, and in many cases do, control in addition signals for movements other than over the track above mentioned. In order to harmonize the working of this system it is necessary that it should be under the control of one man. This is done by carrying the circuits involved, through an instrument placed in the tower at 15th street, by the use of which the director is not only kept informed, through annunciators, indicators, etc., as to the direction in which traffic may be moved over any track at that particular instant, but by pushing a button he may change, positively, the direction of traffic over any track between two adjacent interlocking plants. The pushing of this button not only does this, but in addition it records that fact, and at the same time transmits the information to the adjacent tower so affected.

A feature worthy of note is that concerning information between the tower at 15th street, and the men on the platform and at the gates, concerning the starting of trains. A short time before a train on a certain track is scheduled to start, the conductor informs the tower that all is ready by pushing either one of two buttons (the one he happens to be nearest) along the edge of the platform. By so doing he elevates the hammer of a single stroke electric bell, which by closing its own circuit, retains the hammer in the elevated position, and the circuit thus established drops an annunciator and taps a bell in the tower. The train director, upon observing this information, pushes a button, which breaks this circuit, restores his annunciator, and allows the suspended hammer of the bell on the platform to drop, thus acknowledging the receipt of the message. The director in the tower then pushes another button which operates an indicator placed at the gate where the ticket

inspector is stationed, telling him that he (the gateman) is in possession of the ability to clear the train starting signal. At the same time, the act of pushing this button in the tower records, by a drop annunciator, the information to the director that he has performed this act. The time arrives for the train to go, the gateman closes the gate and turns a knob located on the lower part of his indicator case. This act clears the train starting signal which, in so doing, operates an indicator in the tower informing the director that the train is about to start. If not previously done, he now calls out the route to the levermen, who proceed to arrange the switches and clear the signals in the manner indicated and the train proceeds through the yard towards its destination.

At about the time the train leaves, the director pushes another button—the third and last in the cycle—which restores the starting signal, the gateman's indicator and his own annunciator and indicator to their normal positions.

Should, however, the train movement under consideration be West bound instead of East bound, it may be executed from one of three tracks, on the Ft. Wayne side, or from a like number on the Panhandle side of the train shed. In such a case exactly the same sequence of operations is performed, except that instead of the director in the 15th street tower calling out a route, one is set up by either of the towers on the Ft. Wayne or Panhandle side, as the case may be, from information automatically conveyed by an indicator operated by the starting signal.

Information concerning trains approaching the terminal from each of the four directions, i. e., the P. R. R., Allegheny Valley, Ft. Wayne and Panhandle is conveyed to the various towers interested by train describers, the simplest pos sible means. The sender pushes one of a series of buttons on which is written the information (such as the character of the train and the track on which it is approaching), which he desires to send. This act releases and sets in motion a mechan-

ism which closes and opens a circuit a certain number of times until arrested, thereby actuating the electrical mechanism of the receiving instrument or instruments which are on this line, thus causing the finger to point to a button or disc on which is written the same legend as that on the sending button. East Liberty, for instance, pushes a button, which is then automatically repeated in the towers at 21st and 15th streets.

As additional means of communication there is the usual telegraph, and an extensive telephone system.

The work of installation commenced Sept. 15th, 1901, and was completed March 15th, 1902, a period of six months, including but little favorable and much unfavorable weather.

An item of some interest is that $5\frac{1}{4}$ miles of detector bar was applied, which required the drilling of 42,000 holes through the web of the rail and related parts.

It may be said that the track facilities are in excess of the present requirements, but it is surely a wise policy which builds with an eye to the future.

The following data regarding traffic and lever movements, as well as other information, was secured through the courtesy of Mr. A. M. Keppel, Assistant Train Master, in charge of all passenger and freight service using the terminal, to whom it is desired to extend thanks for the assistance which he has thus rendered.

Description per day of 24 hours.	15th Street Tower.	21st Street Tower.	Washington St. Tower.	Liberty St. Tower.	Hours Worked by each.
(Number of)					
Passenger Trains	134	134	70	43	....
Freight Trains	97	97	44	53	....
Pass. & Frt. shifting movements	2513	1314	664	186	....
Total Train Movements	2744	1545	778	282	....
Lever Movements	23045	10894	4257	1220	....
Telephone Calls	2946	1082	341	543	....
Train Directors	3	3	3	0	8
Assistant Train Directors	3	0	0	0	8
Train Directors Clerks	3	0	0	0	8
Levermen	7	6	3	0	8
Levermen and Operators	0	0	0	3	8
Telegraph Operators	2	2	0	0	12
Signal Foremen	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	....
Signal Repairmen	2	2	$1\frac{1}{2}$	$1\frac{1}{2}$	12
Signal Fitters	2	2	....	....	12
Signal Lamp Men	1	1	$\frac{1}{2}$	$\frac{1}{2}$	12

In addition to the foregoing, 15th street tower has telephone connections with sixteen other points. The men called Assistant Train Directors operate these, whose duty it is to gather information respecting the make-up of trains, the probable time of departure from the various train dispatchers of the several railroads entering Union Station, inform the Station Master, Baggage Agent, U. S. Mail transfer clerk, etc., as to the location of trains in the station, and other information that would be of use to them.

The duty of those men marked Train Directors' clerk, is to answer the Train Directors telephone, and collect and distribute information to the towers at Washington street, Liberty street and 21st street, and assist in the manipulation of the trains between these several towers.

The Train Directors' clerk has a direct telephone to each of these towers for this purpose.

In comparing the cost of operating the switches and signals by the Electro-Pneumatic system, with that of the mechanical system, as to the number of levermen required, it will be noted that at the 15th street tower there are seven men. Experience has shown that the ratio is about one in six in favor of the Electro-Pneumatic, so that this tower would require 42 men if mechanical. The 21st street tower would have 36 instead of 6 as at present. Washington street tower 8 instead of 3 and Liberty street tower 5 instead of 3. The later two towers, on account of their small size, do not maintain the same proportion that the large ones do. However, as a total for all towers we have 19 men for the Electro-Pneumatic as against 91 men for mechanical system, leaving a balance of 72 men in favor of the former system, whose salary would in a short time, amount to the entire cost of the plant.

A still further saving is effected in the matter of maintenance, but no definite figures can be given.

As the duties of all other men employed about the signal towers are in no way connected with the handling of the switches and signals, their number is not affected by the system employed.

CHAIRMAN—Gentlemen, shall we discuss the paper or shall we postpone the discussion until another meeting?

MR. JOHNSTON—I move that we adjourn.

Motion carried, 10:55 p. m.

CHARLES W. RIDINGER, *Sec'y.*

CHEMICAL SECTION.

The regular meeting of the Chemical Section was held in the rooms of the Society Thursday evening, June 19, 1902, the Chairman, Dr. K. F. Stahl, presiding. The evening was devoted to discussion of the Convention of the American Association for the Advancement of Science, with some plans relating to the part of the Section, in contributing to the success of the Convention.

Upon motion the section adjourned at 9.30 until Thursday evening, September 18th, 1902.

CHAS. H. RICH,
Secretary.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

A special meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Room of the Society's house, 410 Penn Ave., Pittsburg, Pa., Tuesday Evening, April 2, 1902, at 8.45 o'clock, the President, Mr. Charles F. Scott, being in the chair and 90 members and visitors present.

This meeting, under the auspices of the Reception Committee, was a very pleasant affair.

Messrs. Snyder and Smith, of the Bell Telephone Co., sprung an unique surprise in a couple of arc lamps, which could sing, whistle and talk loud enough to be heard all over the room.

Mr. Albree entertainingly related his experience when abroad last summer, as delegate of the Society at the International Engineering Congress, Glasgow.

THE ARCOPHONE, OR SPEAKING ARC LAMP.

The "arcophone," as its name implies, is an arc lamp made to speak. The arc lamps used in this demonstration are two Schuster hot wire 110 volt D. C. constant potential standard style, taking about seven amperes each.

The only 110 volt direct current obtainable for these experiments was furnished by Mr. Earl Marvin, of the National Biscuit Co., from a motor circuit in their factory just back of the lecture room. A motor circuit is not exactly the best source of current supply for this experiment. The impulses due to the brushes of the motors running over the commutator bars make the arcs slightly noisy.

The other apparatus used in this experiment was loaned by the Central District and Printing Telegraph Co., and consists of iron clad repeating coils, common battery transmitters, and Western Electric rolled condensers.

Figure No. 1 shows very plainly the wiring of the circuit. It consists of an arc circuit and a transmitter circuit. The transmitter is used to make a pulsating current in accordance with sound waves that strike its diaphram. The repeating coil transforms the pulsating current from the transmitter circuit to the arc circuit. The condensers serve to make shorter circuits for the pulsating currents. The condensers also serve to cut down the natural pulsations of the current in the motor circuit, which otherwise would make a noisy arc. The resistance lamp cuts down the current to the proper amount for the transmitter circuit. The arc transforms the pulsating current into sound waves.

Several theories have been advanced as to what causes these sound waves to issue from the arc. The most logical explanation appears to be the one giving the cause as the sudden expansion and contraction of the air due to the variations of the temperature of the arc.

When a person speaks into the transmitter the sound waves striking the diaphram cause the current to pulsate in the transmitter circuit. This pulsating current sets up similar pulsations in the arc circuit through the repeating coil. The temperature of the arc varies as the square of the current passing through it. As the arc is composed principally of carbon vapor in a high state of molecular vibration, it would have a very low specific heat. The temperature of this vapor varies almost instantly with the current. When this current is pulsating the temperature of the arc is raised or lowered correspondingly. The volume of vapor is increased or diminished in accordance with its temperature. Hence the volume of the vapor increasing and diminishing sets up sound waves in the surrounding air.

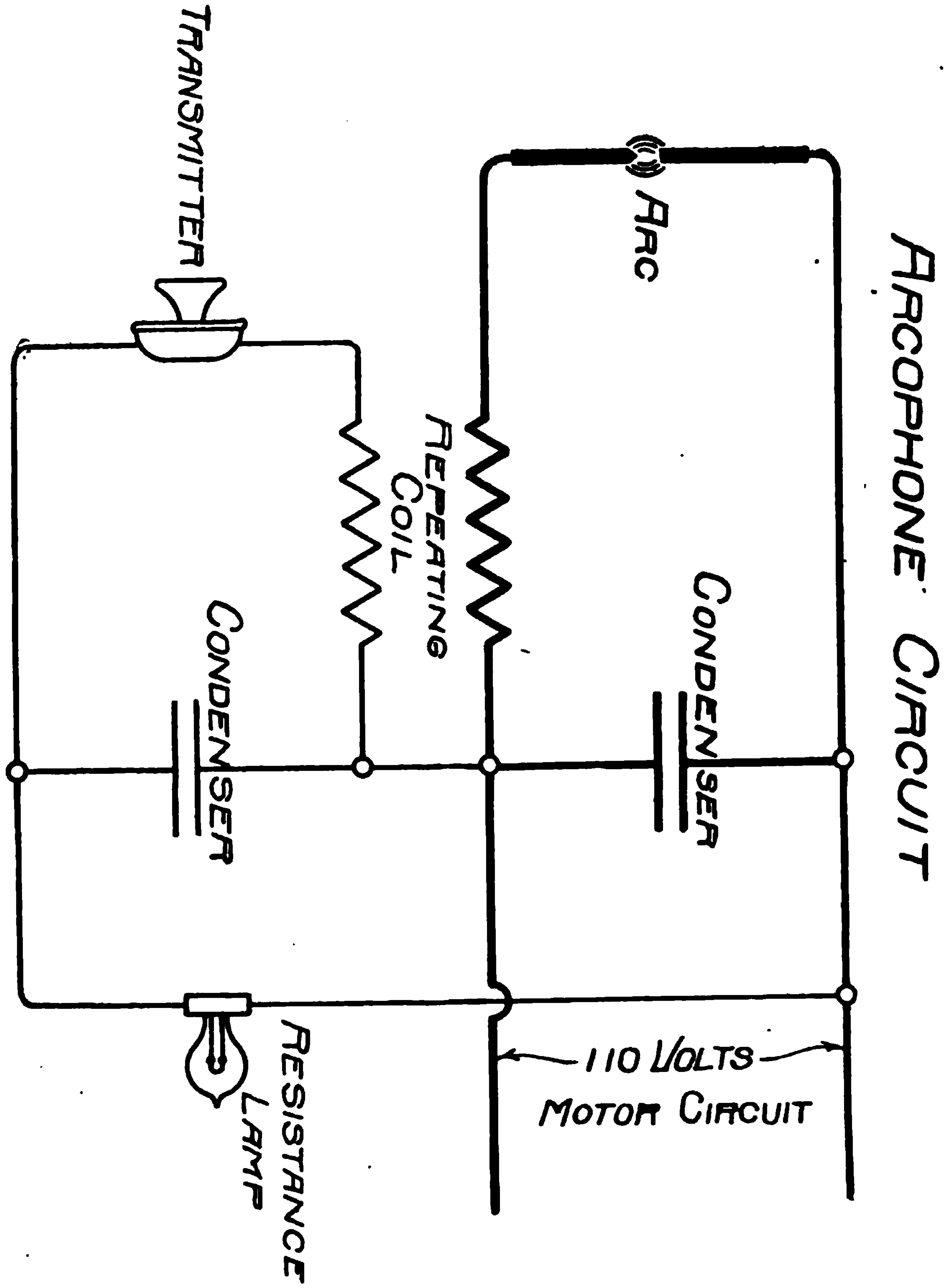

Arcophone Circuit
Arc
Transmitter
Repeating Coil
Condenser
Condenser
Resistance Lamp
110 Volts
Motor Circuit

Figure 1

Through the four transformations just described we have been able to reproduce speech, music, whistling, etc., of very excellent strength, quality, and timbre.

It would be rather surprising to most people if, in the very near future, all the arc lamps in town suddenly began to announce the current events of the times. With our present knowledge such a thing is possible.

The speaking arc lamp will probably have a great commercial value in advertising.

The success of this evening's exhibition has been greatly due to the excellent instruments loaned to us by the Central District and Printing Telegraph Co.

Yours truly,
G. K. SMITH,
R. A. L. SNYDER.

THE GLASGOW ENGINEERING CONGRESS.

In the spring of 1901, the Engineers' Society of Western Pennsylvania, received an invitation to send a delegate to the International Engineering Congress, to be held in Glasgow, September 2nd, to 6th, during the exhibition.

The writer was appointed as delegate and due notice sent to the Secretary of the Congress.

Arriving in Glasgow, a few days in advance of the meeting, gave an opportunity to see something of the second city of the Empire, and the metropolis of Scotland.

Situated on the river Clyde, some twenty miles from the mouth, this city which had but 70,000 population in 1800, now numbers over 800,000 souls, and is noted as the greatest ship building center in the world. The Clyde, formerly a small tide water stream, by reason of dredging and dock building, extending over a century, and costing nearly £40,000,000 has become navigable for the largest ocean steamers, its banks are lined for miles with extensive ship yards, and its docks contain vessels trading to all parts of the world.

Glasgow, however, depends for its prosperity, not only on its ship building and commerce, but is one of the greatest manufacturing cities of Great Britain, especially in cotton and woolen stuffs, iron and steel products and the manufacture of chemicals. The abundant coal fields of the neighborhood, together with a net work of railways have contributed much to its prominence.

The civic government is held up to all the world as a model of how a city should be managed. All street cars, water, gas and electric lighting plants belong to the corporation, and are economically and well managed.

The city is well built, well paved, lighted, modern and up-to-date in appearance, smoky and grimy; almost as Pittsburgh is, but historically and picturesquely not to be compared with its neighboring city Edinburgh.

The University of Glasgow, an old chartered institution, beautifully located on a hill overlooking the city, has long been celebrated for its courses in science and engineering, and has numbered among in its faculty, such famous men as Watt, Rankine and Kelvin. The buildings, of stately appearance, and ample size, were placed at the disposal of the Congress, and proved excellently fitted for the purpose, with the large Bute Hall as headquarters and the various lecture rooms for the section meetings.

The Congress was organized under the auspices of the established engineering societies of Great Britain, including the Iron and Steel Institute, the Institution of Civil Engineers, the Institution of Mechanical Engineers and others, and delegates were present from the Engineering Societies of Europe and America. Every detail was worked out with great forethought and care, resulting in wonderfully smooth and efficient working. The various branches of Engineering were assigned to special sections, and all papers were printed in advance, thus permiting members to prepare their discussions carefully, adding greatly to the interest. The subjects treated by sections were

Railways, Waterways, Mechanical Engineering, Iron and Steel Manufacturing, Mining Engineering, Municipal Engineering, Gas Engineering and Electrical Engineering.

The attendance was nearly 2,500 of whom about 300 were from foreign countries. The sectional meetings were very well attended and the discussions live and to the point. A striking feature was the large number of middle aged and elderly men. Lord Kelvin was chairman and addressed the opening meeting.

The various works of the neighborhood were opened for the inspection of organized parties, and every opportunity offered to visitors to see and understand the operations in progress. Owing to the great number of visits, one had to select those most interesting to himself. The writer chose the Fairfield Ship Building and Engineering Works, an old established and very large ship yard, building war vessels and large ocean steamers. Several large vessels in various states of completion were visited, as also the machine shops, forges foundry and cabinet work departments. Speaking generally, the machinery was massive and strong, but of rather antiquated design. The facilities for economically handling work were especially conspicuous by their absence, much being done by hand, or on small trucks, and with jib cranes, thereby differing greatly from such appliances as are to be seen at the Newport News Ship Building Yards and elsewhere in America.

Much work on the vessels that is accomplished here with pneumatic tools, is done there by hand. One of the guides stated that the reason such tools were not used, was owing to the refusal of the laboring classes to handle them, on the old workman's theory that there is just so much work to be done, and anything that reduces this amount of work, reduces the number of men required. The average British workman is not so well educated or so bright as the American workman, and does not see that he, himself, is the cause of the loss in trade English manufacturers are experiencing. The proprietors and

managers, most of them, fully appreciate the merits of modern machinery and methods, and are very much alive to the necessity of their general introduction, but are, to a great extent, powerless against the organized forces of ignorant workmen controlled by professional agitators and walking delegates.

The social features of the Congress were numerous and well organized. Starting with a banquet for the foreign delegates and officers of the various British Societies, held in St. Andrews Hall, a noble room, containing a very large organ, followed a reception given by the head Provost and aldermen, at the City Chambers, to which some three thousand or more guests were invited. Speeches, music and refreshments, and examination of the beautiful city building served to make the occasion very enjoyable. Still later in the week a large ball was given at St. Andrews Hall.

In addition to the visits to engineering works there was a series of pleasure excursions, for both men and women, to various beautiful spots near Glasgow, including visits to Loch Lomond, the harbor and neighboring firths or bays, and to Edinburgh and the Forth Bridge, all admirably planned and carried out. The attendance was very large, so much so that arrangements to handle all who wished to go could not be made, and alternate excursions were offered to those unable to join the large parties. A system of blanks, containing descriptions of excursions were submitted to members, and filed in order of receiving them, the first in, having precedence in choice of excursions, which were limited as to the number of guests.

The Glasgow Exposition, located in a fine park, just opposite the University building, was thrown open free to the members. It was much like other such fairs, having a main building for manufactured goods, machinery hall, art gallery, government buildings, etc. The buildings were large and tasteful, and the exhibits plentiful and well arranged. In machinery hall a great deal of machinery of different sorts was in active operation. Modern design machine tools, engines and electric

machinery were seen, not only of English, but of foreign make, including much from the United States.

Perhaps the most notable feature of the exhibition was the loan collection of paintings in the beautiful, permanent Art Gallery, embracing, as it did, a comprehensive exhibit of British pictures from early times to the present, and a very large number of fine canvasses of French masters. Critics said it was perhaps the finest collection ever gathered together in Great Britain.

The large athletic field attached to the exposition, with contests of all kinds in field sports, proved an enjoyable feature. Perhaps the most remarkable feature of the whole fair was that at its close, a large balance of profit remained, after paying all bills, which was given to the permanent Art Gallery.

The reception of foreign delegates was very cordial and every effort was made to add to their comfort, profit and pleasure. While the foreign delegates took little active share in the meetings, yet the general results, both technical and social of the Congress, cannot but add to the advancement of Engineering.

CHESTER B. ALBREE.

After the reading of the papers the members and friends adjourned to the Society parlors where refreshments were served.

CHARLES W. RIDINGER,
Secretary.

PROF. A. E. FROST,

TREASURER OF SOCIETY, 1880 TO DATE.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and twenty-seventh regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture room of the Society's house, 410 Penn Avè., Pittsburg, Pa., Tuesday evening, Sept. 23, 1902, at 8.15 o'clock. President Mr. Chas. F. Scott being in the chair, and 134 members and visitors present.

The minutes of the preceeding meeting were read and approved.

The Board of Direction report that they had passed favorably on the following applications for membership and present same to the Society for action.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
ADOLPH F. CHRISTMAS,	Designer for Westinghouse Machine Co., East Pittsburg, Pa. h. Willard Ave., Pittsburg, Pa.	Richard Hirsch, Chas. F. Scott, E. S. McClelland.
REINHARDT DAAE,	Draughtsman, Jones & Laughlin, S. S., City. h. 246 Lehigh St., Pittsburg, Pa.	F. L. White, Victor Beutner.
CHAS. R. DALLAS,	Pres. Dist. Manager, Bullock Electric Mfg. Co., Pittsburg, Pa. h. 3341 Forbes St., Pittsburg, Pa.	C. W. Ridinger, Richard Hirsch.
ALFRED J. DIESCHER,	Mechanical Engineer Member, Firm of S. Diescher & Sons 714 Hamilton Building, Pittsburg, Pa.	S. Diescher, W. L. Scaife.
HARRY C. GOULD,	Assistant Engineer, U. S. Engineers' Office, Pittsburg, Pa.	T. P. Roberts, J. W. Arras.
GEO. T. LADD,	Mechanical Engineer, Bass Foundry & Machine Co., Fort Wayne, Ind.	S. B. Ely. R. J. Arthurs.
WALTER C. KERR,	Mechanical Engineer, President Westinghouse Church Kerr & Co., First Vice-President Westinghouse Machine Co., 10 Bridge St., New York City, N. Y.	Chas. F. Scott, A. M. Mattice.

J. M. MERRILL, - - Manager, - -		{ C. W Ridinger, H. D. Hershey.
	General Electric Co., Pittsburg, Pa.	
HENRY S. MOULD, - President, - -		{ Richard Hirsch, C. W. Ridinger.
	The Henry S. Mould Co., Manufacturer of Briquetting Machinery, Empire Building, City.	
F. NAN McMULLIN, - Designer, - -		{ T. S. White, S. B. Whinery.
	Heyl & Patterson, 1406 Chartiers St., Allegheny, Pa.	
ROBERT M. PEARCE, - Engineer, - -		{ E. F. Wendt. Rawdon Evans.
	P. & L. E. R. R. P. & L. E. Division. 1117 4th Ave., Beaver Falls, Pa.	
GUY P. THURBER, - - Partner, - -		{ C. W. Ridinger, Richard Hirsch.
	Pittsburg, Engineering Co., Pittsburg, Pa. h. N. Euclid Ave., Pittsburg, Pa.	

It was voted that the Secretary cast a ballot electing the candidates to membership.

The Board also report that the House Committee had finished the following improvements in the house:

1st. The room under lecture room was cleaned out and put in shape to store the library temporarily. All books and book-cases in the lecture room, also unbound proceedings and periodicals in the store room were removed to room under lecture room.

2nd. The front hall, stairs, second floor hall, coat room, two front rooms, second floor, lecture room, and vestibule were papered and painted.

3rd. New carpets were furnished for first and second floor halls, stairs, and office on second floor. The floor of lecture room was covered with linoleum. Carpet from office was laid in coat room.

4th. Ventilator was put in lecture room in sky-light.

5th. Old folding chairs in lecture room were replaced with bent wood and new chairs were also furnished for officers.

6th. The store room next to coat room was cleaned out and the partition cut away between the two rooms, increasing the size of coat room. There were also other improvements made, such as electric light wiring, new chandelier for front

hall, curtains and blinds for two front rooms on second floor, light blind for magic lantern, painting officers' table in lecture room, etc. The cost of these improvements will amount to approximately $900.

Mr. Johnson stated that he was not present at the March meeting of the Society, but understood that action was taken at that meeting, whereby a part of the library was to be removed to the Carnegie Library. He then offered the following resolution:

RESOLVED, That the action had at the March meeting, authorizing the Board of Direction to deposit the reference books of our library in the Carnegie Library, be rescinded.

Mr. Scott read from the March proceedings a statement of the action taken.

Mr. Johnson explained the history of the action taken some years ago in connection with the Society moving its headquarters into the proposed Carnegie Library Building.

Previous to erection of that building a movement had been set on foot to provide a permanent house for the Society. The scheme had been thoroughly matured, a site had been selected and an option thereon secured, and an architect engaged to prepare plans. The success of the scheme was fully assured. The Committee having the matter in charge called upon Mr. Gottlieb, past President of this Society, and then President of the Keystone Bridge Co., to have him ascertain to what extent Mr. Carnegie would become a subscriber to the fund. Mr. Gottlieb told the Committee that only a short time previously Mr. Carnegie had informed him (Gottlieb) of his intention to donate to the city of Pittsburg, a library building in which he intended to provide free quarters for all the scientific societies in Pittsburg, and advised the Committee to let their scheme drop.

This was done. Mr. Carnegie carried out his declared intention. The various societies were asked to designate the space required, which was furnished, and included in the pre-

liminary plans. The house was built, but with the accommodations for the societies largely curtailed and modified.

When the building was nearing completion the Trustees invited the officers of this Society to meet them at the building, to arrange terms under which we might avail ourselves of Mr. Carnegie's generosity. At that meeting the Trustees demanded,

1st. That our Library should be moved into and become a part of the general public Library.

2nd. That the Societies jointly should pay the salary of the Curator ($3,000 named), of which the proportion falling to the Engineers' Society would be about $2,400 or $2,500.

To have accepted this proposition would have left the Society, out of its revenues, only $300 or $400 per year for all other expenses. We would have been compelled to abandon the publication of our proceedings, dispense with a paid Secretary and other features; with the result that the Society would have died of inanition in a very short time.

Furthermore, one of the Trustees took it upon himself to say that if the Engineers' Society refused to avail themselves of the terms offered, they would be acting in bad faith, but whatever bad faith there was in this transaction does not rest with the Engineers.

Mr. Brashear made some remarks in which he stated that the Society might be thankful that it did not decide to make its headquarters in Carnegie Library, as other Societies who had arranged to hold meetings there had received very poor accommodations and very poor treatment, etc., etc.

Mr. Albree remarked that he had been on the Library Committee for two or three years, and after having gotten the Library in fairly good shape, had hoped that the members would make use of it, but there had not been ten members use the Library last year. It was on this account that the Library Committee favored placing the books with the Carnegie Library where they would be more accessable.

Mr. Stupakoff stated that in his opinion the reason the Library had not been made use of more extensively was, because there had never been a complete index, showing exactly what could be found in the Library.

Mr. Johnson desired to correct Mr. Albree on the estimate of the number times of the Library was referred to the past year, as he feels sure that he personally visited the Library more than ten times himself.

The motion of Mr. Johnson was carried.

Mr. Scott:—Transportation is one of the most important factors in civilization. The developments in transportation and the advance in civilization have in a measure gone hand in hand. The changes which have taken place in methods of transportation during the last century underly the great developments which have taken place in commerce, in manufacture and in social conditions. The problems of transportation have been essentially engineering problems.

The advances which have been made have resulted from the work of the Engineer.

The means of transportation by water, including, on one hand, steamships and on the other hand the improvements of waterways, have been the work of the Engineer. The development of the locomotive and of rolling stock, as well as the construction of bridges and tunnels have been the work of the Engineer.

If you were to take a railroad map and draw a line south from Buffalo through Pittsburg, you would find that there are not more than one or two railroads of importance, which do not come to a focus at Pittsburg or at Buffalo, the two gateways between the east and the west.

Pittsburg is a focus both for railways and for waterways, as two great rivers unite in the Ohio, which leads to the sea.

I was surprised to note a few days ago that the tonnage of the Pennsylvania railway system alone exceeds the tonnage of Great Britain, including that of all its railways and its

ocean traffic. On the other hand, the tonnage of the Pittsburg rivers exceed that of the port of New York with its magnificent harbor and extensive docks and its world wide commerce. The value of the tonnage of Pittsburg by no means equals that of New York, but the problems which confront the engineer are measured by tons rather than by dollars.

The papers to be presented this evening deal both with the railways and waterways of Pittsburg. The two come in close contact in their engineering as well as their commercial relations.

The difficulty and magnitude of the problems presented in this Pittsburg district are equalled only by their far-reaching, industrial and commercial importance.

I have the pleasure of introducing Capt. Wm. L. Sibert, Corps of Engineers, U. S. Army, who is now stationed in Pittsburg.

FULL USE OF THE RIVERS AT PITTSBURG AND THE REMOVAL OF THE OBSTRUCTIONS TO SUCH USE.

BY CAPT. WM. L. SIBERT.

Recently in designing Lock No. 2, Allegheny River, the upper mitre sill was placed 10 feet below the pool surface, anticipating that during the life of the lock, barges of 9 feet draught would be loaded from manufacturing plants along the banks of the pool for shipment to tidewater.

We are now passing through a period of abnormal home demand for the products of Pittsburg. Our railroads are all renewing the superstructures of their bridges, replacing their wooden cars with steel cars, laying heavier rails and additional tracks. We are inaugurating a wonderful system of suburban electric roads connecting our cities. We are tearing down our stone and brick buildings and replacing them with steel frame structures; this in connection with remarkable prosperity everywhere, accounts for the present abnormal home demand. To meet this demand, we are building, as fast as we can, additional manufacturing plants. The time must surely soon come when the home demand will be normal and many of the plants now in operation must look for a foreign market for their products. When that time comes, cheap transportation to tidewater becomes a vital question, and to those cities with equal natural advantages, the one that can solve most cheaply the question of transportation to tidewater will win.

The world is looking to the far East as a probable market for large quantities of iron and steel products. Partly in anticipation of this, the United States has authorized the construction of an Isthmian Canal; this, in addition to giving Pittsburg

of them were built under State authority, with the result that nearly all the attempts at navigation have been nullified by these bridges and we still see the old keel-boat days in the Allegheny.

The Union bridge at the mouth of the river has a clear height of 35 feet above pool surface. One bridge in the Herr Island pool will have a clearance above such pool of 27.5 feet. The least height of packet that leaves Pittsburg for the south is 45 feet, chimneys down; the least height of larger towboats is 50 feet, chimneys down. The average height of the Monongahela River towboats is about 26 feet, chimneys down; the height of a suitable packet for the Allegheny River would be at least 30 feet, chimneys down.

It is, therefore, seen that the tow and packet boats that transport Pittsburg products south cannot enter the Allegheny River at low water. That a suitable packet for this river could not pass under the bridges in Herr Island pool at low water, and that the towboats suitable for pool towing could not navigate the stream at a stage above 10 feet. We see on the Allegheny River the only steel boat-building establishment in Pittsburg, launching the hulls of its boats and floating them under the Union bridge, and then building the upper part in the unobstructed river below. We see broken shafts of steamboats hauled by wagons around this bridge to the same place for repair. This forces much work elsewhere for execution. We see manufacturing plants on the Allegheny hauling their products by wagons to the Monongahela or Ohio River for shipment to lower Mississippi River points, paying half as much for this hauling as it costs to transport the same material 2,000 miles to its market.

The Union bridge at the mouth of the Allegheny should have a height of 70 feet above pool, thus enabling the harbored craft to seek either river for safety in case of floods or running ice in the other. The ice ordinarily comes out of the Monongahela several days before it does out of the Allegheny. Above the Union bridge it is thought that a clear height of 50 feet above Davis Island pool will be sufficient to Brilliant.

PITTSBURG HARBOR.

This harbor extends from Davis Island Dam to McKeesport on the Monongahela, and to Brilliant on the Allegheny. On the Monongahela nearly all the available sites for manufacturing plants are taken up for 30 miles. On the Ohio the same condition will immediately follow the completion of the dams now under way; this leaves the Allegheny the undeveloped section and the only section left for Pittsburg's growth in manufacturing plants.

If the bridges were raised by the time the locks and dams at present under way are completed, so that free water communication existed between the three streams, what uses could be made of it to cheapen Pittsburg production and relieve the present terminal difficulties?

All of the material needed at the various structural works could be transported from the mills more cheaply and much quicker than now by rail. Take for instance a pressed car works that requires 1,500 tons of steel a day. Let this establishment build 10 500-ton barges at a total cost of $25,000. It could then purchase its steel loaded at the mill, and could have its towing done at a cost of less than 2c per ton, up to a distance of 10 miles; the entire amount of material could be delivered in about 2 hours' time.

Apply this system to all similar transfers in the harbor, and one can easily see that it would materially reduce the congestion of cars in Pittsburg and enable the railroads to haul the products away from Pittsburg. If this did not reduce the congestion sufficiently, the railroads could build boats for transferring cars loaded and unloaded to and from the various plants to points on the three rivers away from the congested center, and then haul them away. Such facilities would enable new railroads entering Pittsburg to reach the various manufacturing establishments by transfer boats, as is done in New York Harbor, more cheaply than they could do it in this congested center by cars, assuming that it is practicable at all

for new roads to reach many of our establishments by cars. Transfer barges capable of transferring as many as 22 loaded cars at a trip can be, if necessary, built and passed the locks just authorized on the Monongahela. Consideiing the limited space in the Monongahela Valley and its already congested condition, the manufacturing establishments of Pittsburg should see that they are not barred from inclines to the river, not only for the purpose of river transportation, but for the purpose of additional railroad facilities.

Nature has made it practicable to give Pittsburg similar facilities to those in New York in the way of handling freights. In connection with the subject of extending transportation facilities in and about New York, the following quotation from the Engineering News is pertinent to the condition at Pittsburg:

"The fact is that instead of the North River being a barrier to traffic under present conditions, it is really a vast distributing yard with its tracks always maintained free of cost, and in which a train can move from one point to any other without obstruction or delay.

"Nor is this yard limited in extent to the North River. The car float goes from the Jersey City pier to any point on the East River, the Harlem River, or the harbor, and by reason of this enormous mileage of water front the loaded freight car can be delivered at a warehouse close to its final destination at less total actual cost than the switching charges for similar transfer in any other great city of the country."

The records of the last 30 years show that on the average the stage of water in the Harbor of Pittsburg is 9 ft. or more above pool stage, i. e., above 15-ft. stage, 10.7 days per year; that it is above the 20-ft. stage 5.5 days per year; that the greatest number of days in any one of the last 30 years that navigation was interfered with by the Monongahela River bridges in the Harbor was seven. The surface of the water is practically at pool stage about 8 months in the year, from which it would appear that the difficulties of a car transfer

system in Pittsburg Harbor should not exceed those in a tidal harbor with its tidal currents and daily variations in water level.

These uses imply an unobstructed harbor and a harbor of sufficient depth at all times. Modern conditions demand certain and continuous means of transportation, and the conversion of Davis Island Dam into a fixed dam, in producing this condition, is one of the questions under consideration now. If this were done and the bridges raised, no reason is seen why these uses, and many more that could be mentioned, could not be realized.

Galveston rested secure in the feeling that the wind would not blow with high velocity from a certain quarter for a greater length of time in the future than it had in the past, and awoke one night in a terrible catastrophe.

On March 1st last the Allegheny River rose to a stage of 34½ feet at 22nd street. This rise was produced almost wholly from melted snow. Had there been at the same time an inch of rainfall over the valley of the Allegheny, a very frequent occurrence, the above stage would have been increased probably as much as 5 feet, enough to reach the superstructure of nearly every bridge across the Allegheny within the City of Pittsburg. What would be the result of such a flood, bringing with it the winter's ice out of the Allegheny? The probabilities are that the superstructures would be taken off the bridges, lodge against the piers below on which the ice would gorge and the destruction of life and property would be appalling. The possibility of this should be eliminated.

The removal of all obstructions to the full use of the lower portion of the Allegheny would result in a remarkable development of the Allegheny Valley, a development commensurate with the expenditures for river improvements, and Pittsburg would be the trade center of the developed section.

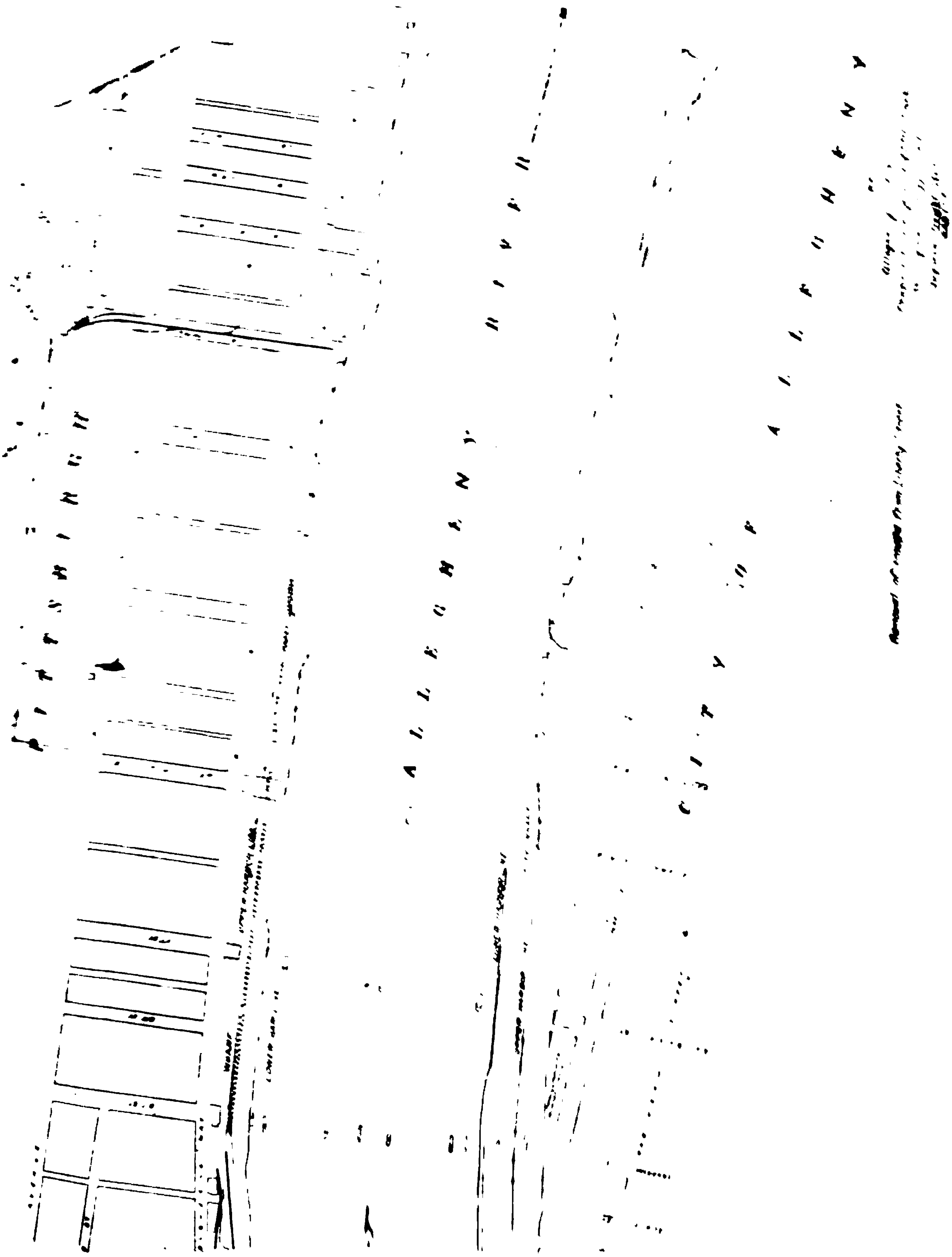
While knowing nothing as to the plans of or necessities for warehouses or freight depots on the Point, it is an evident proposition that it would be an advantage to Pittsburg to have

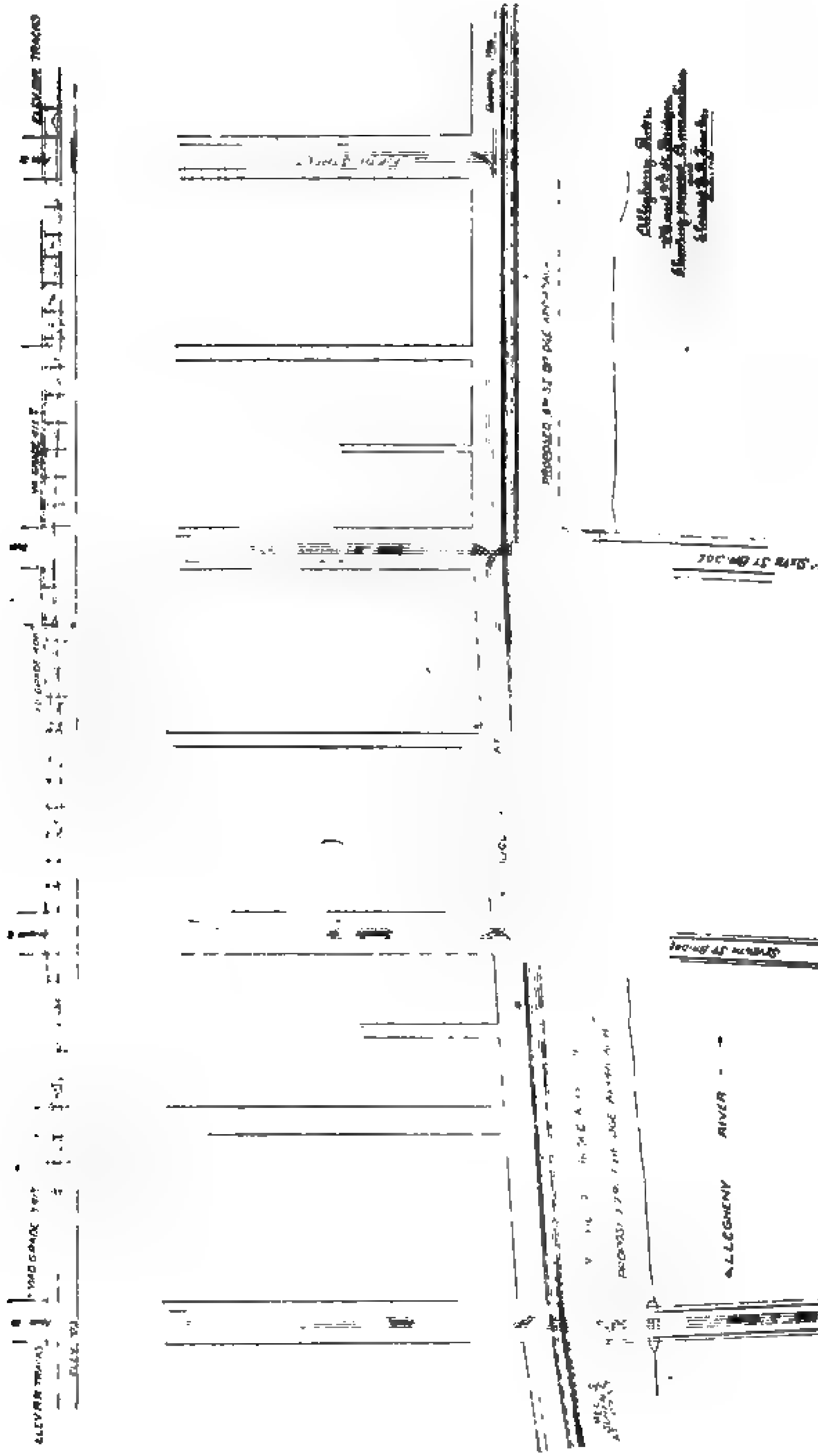
the railroad tracks removed from Liberty street. The raising of the bridges makes it practicable to do this and to make better connections to such warehouses or depots by surface tracks passing under the elevated approaches to the bridges than exist now. An approximate location of such tracks can be seen on the plans to be presented later. In case elevated tracks are desired instead of surface tracks, the raising of the bridges will not interfere with that plan, as can be seen on drawings herewith.

The approaches to the raised bridges on the Allegheny City side involve changes in street grades on two streets only, viz: Grant and Chestnut. The approaches to the 6th, 7th and 9th St. bridges remain as they are now. Such approaches on the Pittsburg side involve changes in street grades at 16th, 30th and 43rd streets only, eliminating grade crossings at 30th and 43rd streets. On the two ends of the raised 43rd street bridge, grade crossing of 13 railroad tracks, including 2 main-line railroads, are converted into overhead crossings.

The maximum grade in approaching the raised bridges will not exceed the maximum grade found on some of the bridges now.

In connection with this subject the following extract from Congressional Record of March 17th is quoted—Mr. Reeves. * * * * "When a bridge is lawfully in its place, either by Act of a State or by an Act of Congress, if the Congress in giving its assent does not reserve the right to alter or amend or repeal the provision authorizing its construction, but without limitation gave the Company the right to build it, my opinion of the law is that the Government cannot alter it nor change it without paying the expense in doing so."


ALLEGHENY RIVER
CITY OF ALLEGHENY
PITTSBURGH


ALLEGHENY RIVER

PRELIMINARY STUDY WITH SKETCHES SHOWING A PLAN FOR RAISING BRIDGES IN THE ALLEGHENY RIVER.

Union Bridge.—This bridge is now old and not serviceable for heavy traffic. It will be necessary to rebuild it before it can be so utilized. A new bridge is assumed in this case. The Point Bridge has the elevation that this bridge should have, and there seems to be no reason why the Pittsburg approach to the Union bridge should not join the approach to the Point bridge, widening such approach if necessary. This approach and the approach in Allegheny City side are shown on blue-print. An approach from Duquesne Way is also shown. See plate No. 1.

Sixth Street Bridge.—The blue-print plan herewith shows that it is practicable to raise this bridge without changing the approach on the Allegheny City side. On the Pittsburg side, viaduct approaches of easy grade, riverward of Duquesne Way, reach street grades at 5th and 7th streets, respectively, with no property damage and at a moderate cost. See plate No. 2 and C.

Seventh St. Bridge.—The width of river between harbor lines between 9th and 6th streets is about 100 feet more than it is above and below. And it is practicable to make approaches to this bridge in the same manner as to the 6th street bridge, starting from 9th and 6th streets as shown on blue-print. On the Allegheny side the approach remains as now. 7th and 9th street bridges have similar profiles, plate 2.

Ninth St. Bridge.—The Allegheny approach remains the same as now. The approach from the Pittsburg side starts at 7th street riverward of Duquesne Way. To give the requisite width of spans it will be necessary to rebuild this bridge.

Eleventh St. Bridge.—The approaches to this bridge are already provided. By abandoning the lower track and lifting the channel span so that the lower track will have the same elevation as the upper track of the other spans, the interests of navigation would probably not be materially interfered with.

Sixteenth St. Bridge.—The approaches to this bridge on both sides of the river involve making fills and viaducts in 16th and Chestnut Streets, as shown on blue-print. This is an old wooden bridge, and a new bridge is assumed.

Thirtieth St. Bridge.—On Herrs Island the necessary elevation conforms to plans desired by the R. R. work planned on that island. On the Pittsburg side the new elevated approach is shown on blue-print.

Thirty-third St. Bridge.—This is the Pittsburgh Junction R. R. bridge. A plan for raising this is shown on blue-print, improving the grade on the bridge over main channel and back channel. This change involves the construction of about 2000 ft. of viaduct on the Allegheny City side, the grade on which will be less than the present grade on the bridge or on the northern approach to it. This, however, interferes with no other interest—is simply a matter of cost. Very little expense would attach to the other work. See plate No. 3.

Forty-third St. Bridge.—Plans for raising this bridge are shown on blue-print. It involves viaduct approaches on 43rd street, Pittsburg side, and on Millvale Borough side. This plan carries the traffic over the Pittsburgh Junction, Pittsburgh & Western, West Penn and Traction Co., tracks, as shown. This would be a boon to the traveling public and to the railroads. This is a wooden bridge thirty-two years old. See plate No. 4.

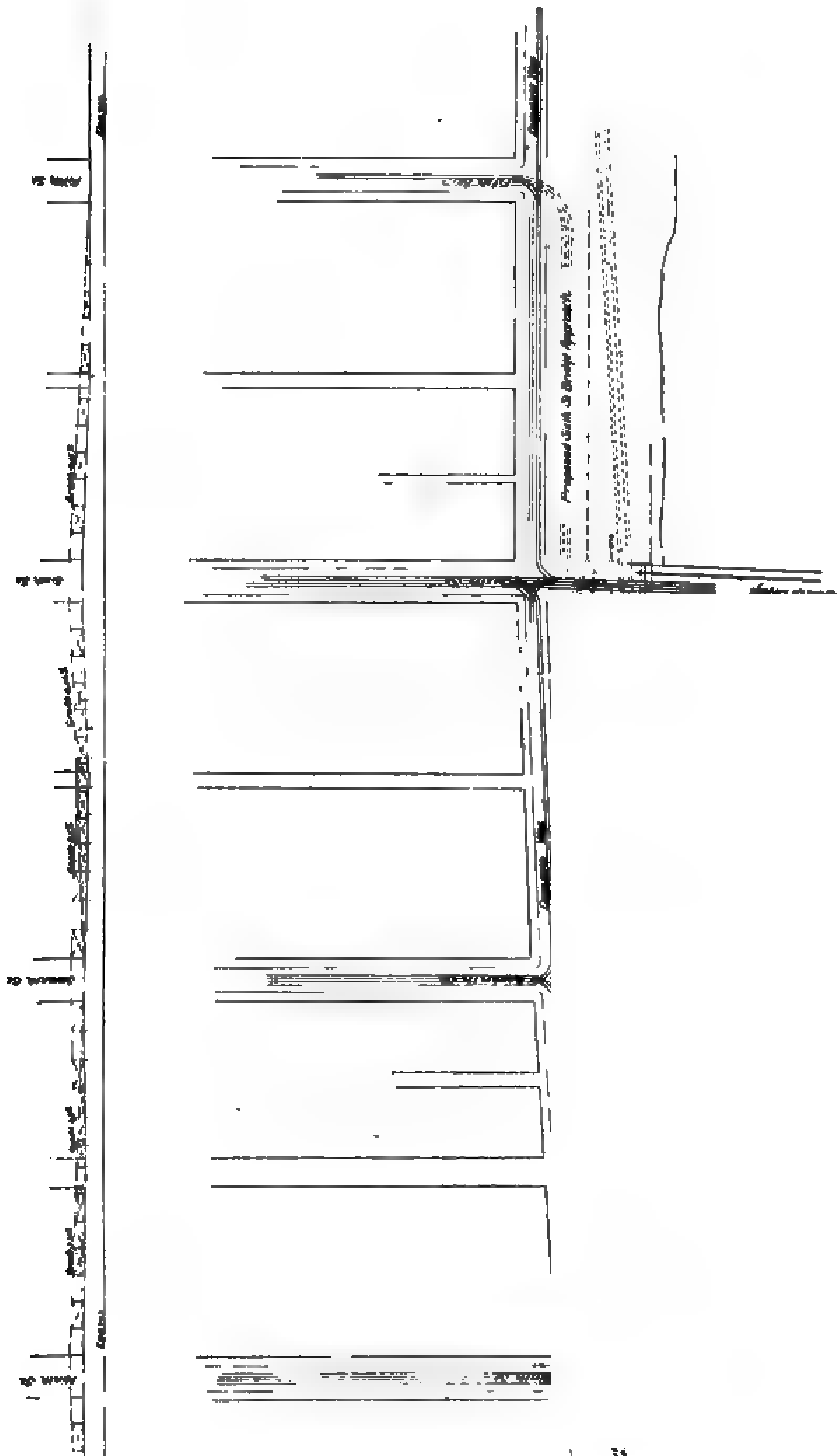


PLATE C.

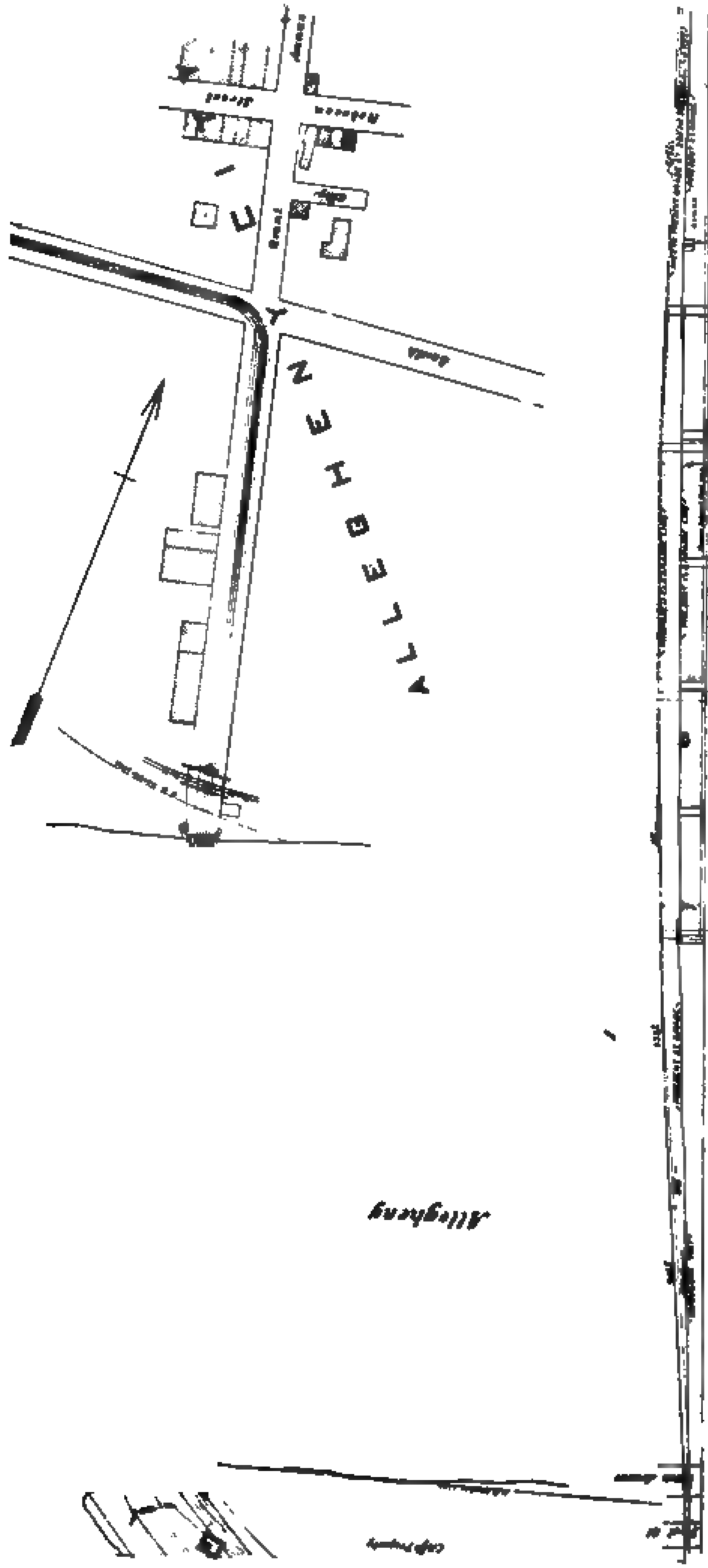


PLATE NO. I.

PLATE No. 2.

PLATE No. 3.

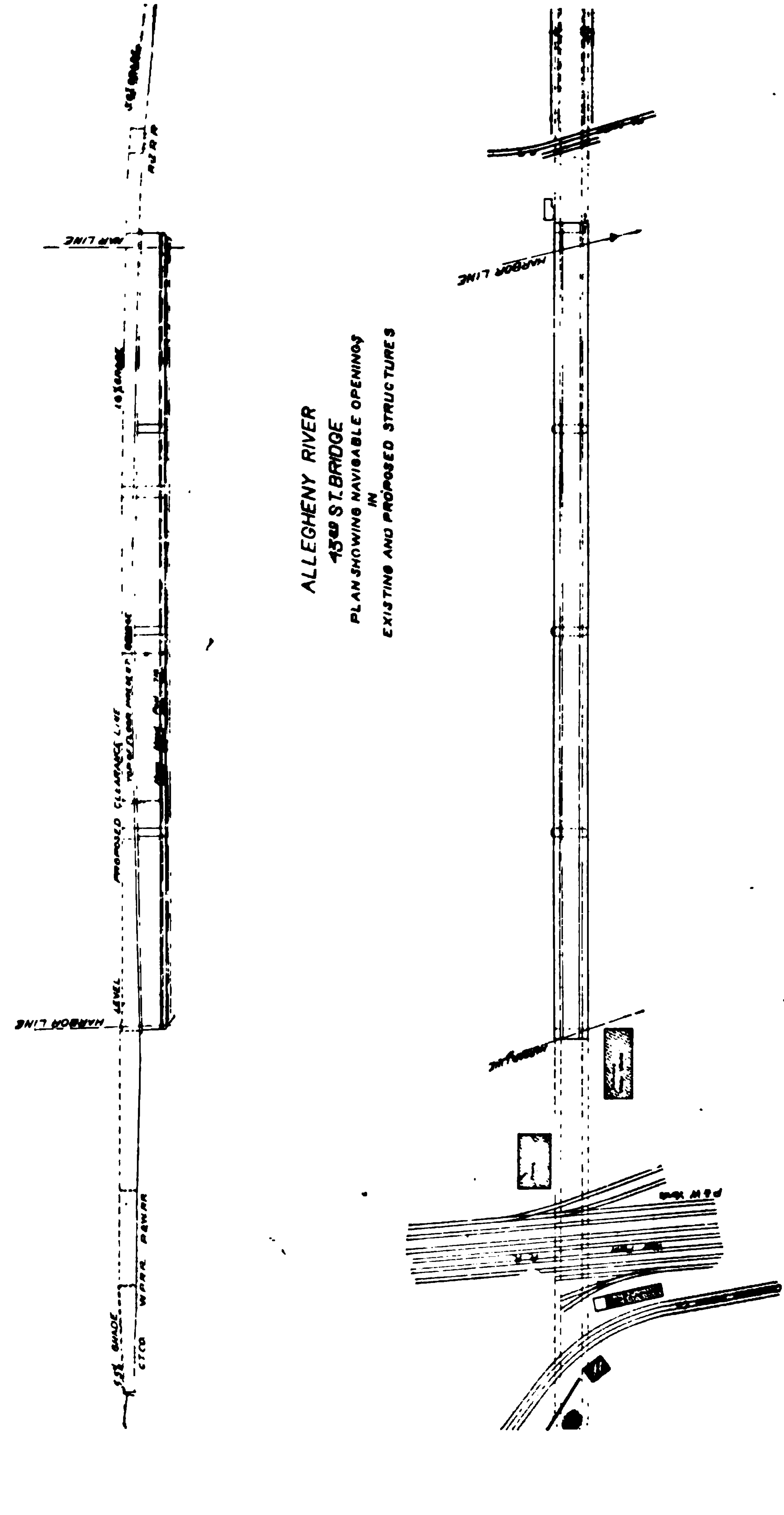

ALLEGHENY RIVER
43RD ST. BRIDGE
PLAN SHOWING NAVIGABLE OPENINGS
IN
EXISTING AND PROPOSED STRUCTURES
HARBOR LINE
HARBOR LINE
PROPOSED CLEARANCE LINE
LEVEL

PLATE No. 4.

DOUBLE DECK BRIDGE FOR P. F. W. & C. RY. CROSSING THE ALLEGHENY RIVER AT PITTSBURGH, PA.

BY MR. E. A. AMADEN, C. E.,
American Bridge Co.

The extensive improvements that were undertaken in Pittsburgh and Allegheny sometime ago, by the Penna. Company in connection with the terminal improvements by the Pennsylvania Railroad, are now well advanced toward completion.

This work includes the track elevation in both Pittsburgh and Allegheny and a modern bridge across the Allegheny River at Eleventh Street. To avoid the grade crossings, that had become a menace to the ever increasing street traffic, it was necessary to elevate the tracks of the Pittsburgh, Ft. Wayne & Chicago Railway.

A double track, solid floor, through plate girder, spans Penn Avenue at Eleventh street, and from Penn Avenue to the bridge crossing the Allegheny River the tracks are carried on a double track steel viaduct.

The bridge crossing the river at this point is a four-truss, double-deck structure, and is 983.96 ft. long, centre to centre of end pins. It is made up of three spans 156 ft. $\frac{1}{2}$ in. centre to centre of end pins, one channel span 333 ft. $3\frac{1}{4}$ in. centre to centre end pins, and one flared span 164 ft. $2\frac{5}{16}$ in. centre to centre end pins. In order to connect with the low grade freight tracks of the West Penn and the Buffalo and Allegheny Divisions it was necessary to design this structure for a lower as wel as an upper floor deck.

To meet these requirements the bridge was designed with four trusses. The P. Ft. W. & C. tracks are carried on the

upper deck on the up-stream side and the low grade tracks on the down-stream side of the lower deck. Provision is also made on the up-stream side of the lower deck for a foot walk.

By referring to the inset sheet accompanying this article will be found a general elevation, plan and cross sections, showing the general outline and arrangement of the structure.

The outside trusses are designed for a live load of 3,750 pounds per lineal foot, plus 37,500 lbs. concentrated weight, all applied at the level of the upper deck. The trusses of the middle opening are designed for a live load of 7,500 lbs. per lineal foot, plus a concentrated weight of 75,000 lbs., 60% applied at the high level and 40% at the low level.

The floor systems were designed for a live load of 5,000 lbs. per lineal foot of track, plus a concentrated weight of 50,000 lbs.

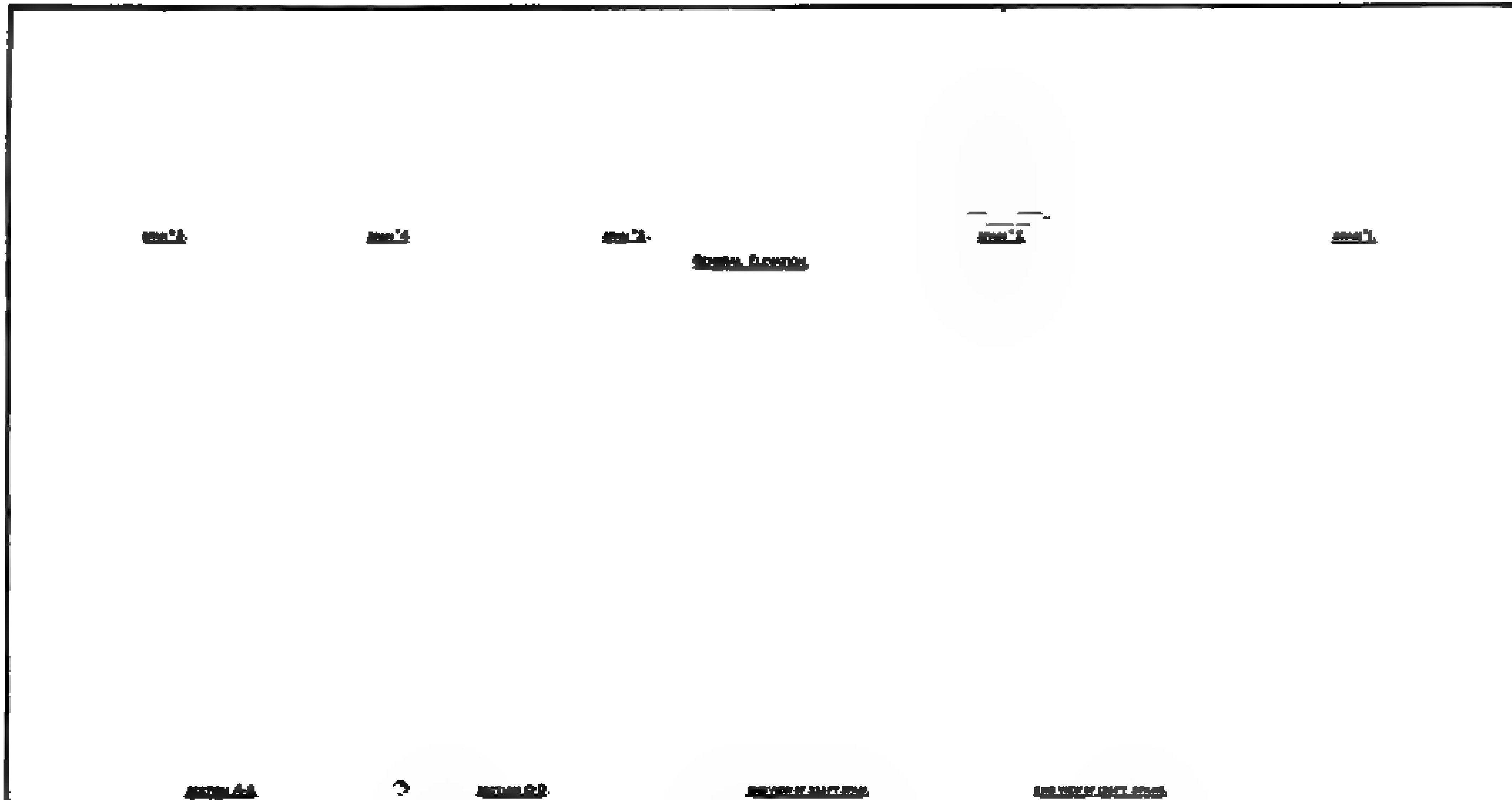
The lateral systems for all spans were proportioned for a static wind load of 30 lbs. per square foot of exposed surface and 600 lbs. moving or 50 lbs. static load.

Impact was added to the web systems in accordance with Penna. Lines West of Pittsburgh specifications, dated April, 1897.

The unit stresses were increased 20% over the allowed unit stresses for soft steel. The material used in the trusses and bracing being medium O. H. steel, and in all members in the floor systems soft O. H. steel was used.

The Penna. Lines standard floor deck was used, and so framed to take out all the camber, giving a level floor under dead load. One half the camber was taken up in the stringers and one half dapped out in the ties.

The design for the foot walk is somewhat novel, inasmuch as the railing was designed as a girder, and carries the floor direct without the use of floor stringers. It was found necessary to provide over the walk a covering for the protection of the foot passengers against falling matter from the tracks above.



DOUBLE DECK BRIDGE, P., FT. W. & C. RY., CROSSING ALLEGHENY RIVER AT PITTSBURG, PA

This has been amply provided for by extending purlins between the cross bracing at the panel points and covering the same with galvanized corrugated steel. The purlins are supported at intermediate points by trusses carried by the sidewalk railing.

Before beginning the erection of the new structure the old bridge was moved down stream 27 feet at the east end and 43 feet at the west end. Six temporary pile supports had been provided to carry the old bridge in its new position. Tee rail bed plates and rollers nest were placed under the old spans, and the same were brought into position with three twelve spool hoisting engines, having a combined capacity of 105 horse power.

The bridge was moved as a whole to a parallel position, so that the Pittsburgh end was in its final position and then the Allegheny end was swung around in its position.

The moving of the old bridge was performed on Sunday morning, and caused but a short delay in the movement of the regular traffic across the river. The approximate weight of iron in the old structure was about 1,300 tons.

The alignment of the P. Ft. W. & C. tracks had been so changed that by shifting the old bridge as before mentioned, the north and middle openings of the entire new bridge, involving the three northerly trusses and their enclosed tracks, could be erected without interfering with the traffic.

Upon completion of the north and middle opening of the new bridge, the old bridge is to be taken down and the south opening of the new bridge erected in place.

The weight of steel in the new structure for span No. 1 is 1,100 tons; for span No. 2 is 2,800 tons; for spans Nos. 3, 4 and 5, 2,650 tons, making a total for the entire bridge of 6,550 tons, exclusive of the steel viaduct approaches.

The erection was begun at the Allegheny end, erecting the three small spans first, then the flared span at the Pitts-

burgh end, and finally the channel span. This method of erection was adopted in order to keep the channel open to avoid any damage by high water during the June freshets.

Upon the completion of this structure the Penna. Company will have a bridge that will meet all the demands that will be required of a structure of this kind for years to come.

ARTIFICIAL LIMITATIONS OF COMMERCE ON OUR RIVERS.

BY CAPTAIN JOHN F. DRAVO.

Transportation is a controlling agency in supplying domestic wants and industrial necessities. Two forms-water and rail are the chief factors in meeting these demands. There is no conceivable reason why these two forms of carriage should not work in harmony and supplement each other in meeting the wants of modern life, but unfortunately they too often are found in hostile array, though it must be admitted that the antagonism comes mainly, if not uniformly, from the rail side. I know of no instance of river interests placing any obstacles in the way of rail movements, unless opposition to shore fills and narrow bridge channel passage ways be so considered. Water ways antedate by many centuries the advent of the rail, and therefore, have priority of right of way, not secured by a hasty survey to prevent competition, but a right of way furnished by the generous provisions of nature, open to all for public or private use. Two forms of obstruction, natural and artificial, interfere with the most desirable conditions of water ways within the territorial limits of the United States. In response to the earnest demands of farm, mine and mill for cheap transportation, the National Government is expending vast sums of money to overcome the natural hindrances to the best navigable conditions of lake and river; but it is a great misfortune, a misfortune that amounts to a public calamity, that private corporations have, and are still adding artificial limitations to the full and free use of our rivers, which work to the greatest possible disadvantage of water way commerce. On the Allegheny River, within the corporate limits of this great city, there exists a condition of bridge obstruc-

tion which only an insane policy of cheapness could have devised, and the domination of corporate selfishness continue.

To fence up the outlet of a great valley, posessing almost boundless elements of wealth, of manufacturing prosperity and industrial growth, by a series of bridges constructed on the money saving plan, is suggestive of a deliberate purpose to cripple, if not destroy, the commerce of the river; and what adds to this unfortunate condition, a great rail corporation is engaged now and has been for months in constructing a bridge across the river which is a disturbing menace to interstate commerce and will continue to embarass and restrict river trade as long as the bridge, in its present form, exists; a bridge built in defiance of every principle of common equity and the earnest pleadings of those who use the river for commercial purposes.

There is no reason in sight that prevents the great and rich Allegheny Valley developing a condition of growth and industrial activity, equal to her sister Monongahela Valley, which is attracting the attention of the manufacturing and commercial world by a growth of population and industrial activity without a parallel in the world's history. No preventing cause but a fenced-up condition of the river, by a system of low bridges with dangerous and destructive narrow channel ways.

Thanking this distinguished organization for the privilege of taking part in the discussion of the evening, I desire to embrace the opportunity thus offered to take a somewhat broader view of the important question of transportation than its local relation to a single community, and briefly consider, in a general way, the best conditions demanded by river commerce as it now exists. These required conditions are determined by the special form of river transportation which prevails on our rivers, known as the "Towing System," which consists of a steamer hitched into a number of crafts loaded with coal, coke, glass, iron, steel and general merchandise, the

length of tows including steamer being, on the upper Ohio, six to eight hundred (600 to 800) feet; on the lower Ohio and Mississippi one thousand to twelve hundred (1,000 to 1,200) feet. The length of a tow determines the required width of passage way for the reason that these fleets are guided or steered at certain points, by what is known in boating parlance as "flanking," that is, the tow is placed in an oblique position while the steamer's engines and wheel are reversed from a forward to a backing movement, allowing the force of the current striking the broad side of the fleet, to carry the mass of tonnage out of a bend or crooked, or dangerous part of the river, but the moment a towing fleet is out of a parallel position with the descending currents, steamer and tow are forced towards one or the other side of the river, requiring large room and great skill on part of the pilot to overcome this drifting and get the tow into a safe and manageable condition, and hence it is manifest that a very wide passage way is an imperious necessity. Sometimes from various causes boat and tow get at right angles with the current, or "broadside," as it is called, and may drift for miles in such a perilous position. Now if a bridge is to be passed, it is very apparent that unless a passage way is wide enough to accomodate the tow in that position, loss must occur, and may involve the whole tow, amounting to many thousands of dollars in value. In our contention for wide passage ways under bridges the losses which have been sustained by navigators are unanswerable vindication of the righteousness of our plea. In a controversy which the writer had with a distinguished engineer of this organization, it was admitted that the loss to the commerce of the Ohio River, by collisions with bridge piers, amounted to more than a million of dollars; add to this the greater loss resulting from enforced tie ups, awaiting daylight to run the narrow and insufficient passage ways, and the additional cost of sending a second steamer as a helper in passing these artificial, dangerous bridge channel ways on the upper end of the river, and there sums up

an aggregate loss of millions imposed upon the commerce of a national highway by faulty bridge construction. It is pertinent to inquire, is there any railway corporation on earth that would tolerate such interference with their rights of transit or submit to such intolerable conditions? In the name of all that is fair and equitable, why should river commerce on waters belonging to all the people be subjected to such great wrongs?

However just and pressing the demands of the commerce of the present for the unobstructed use of the waters of the Ohio and other rivers, the demands of the near future will be vastly more urgent. When the Panama inter-ocean canal is completed, the Ohio and Misissippi rivers will constitute an inland link in a continental waterway reaching the markets of the world, and in connection with the rapid increase of present trade, it is certain that the demands upon the capacity of this far reaching waterway will be almost unlimited, and only unpardonable folly will be allowed to block the way of such a promising future. This anticipated increase of river traffic is justified by the experience of the past and present. Within the memory of the writer a few "floaters" or "broad horns", lashed in pairs, managed by a crew of twenty-five (25) men, carrying a cargo of forty or fifty thousand bushels, supplied the fuel demands from Pittsburg to New Orleans. When the towing system displaced the floaters the cargo of steam tug and barges was not much in excess of a pair of floaters; now a single steamer starts from Pittsburg with a cargo of five hundred thousand (500,000) bushels of coal and from Louisville with a cargo of more than a million bushels, and the cargo of the steamer "Sprague," now nearing completion, will be fifty (50) coal boats containing over a million and a quarter bushels, a cargo equal to twenty-five (25) pairs of old-time floaters. Surely in view of the commercial possibilities of this highway of water transportation it is nothing short of criminal to interpose permanent limitations of its capabilities either for present or future. Our contention for a free and open river, divested

of all artificial limitations, is emphasized with a force that mere words cannot express. The freight congestion which has existed at this great industrial center is a cause of serious alarm to all who are interested in the present and future of our city. Under existing conditions Pittsburg has reached the limit of growth and as a manufactuing center has lost former prestige owing to insufficient shipping facilities. With every available rail transportation outlet blocked by accumulated freight consignments, the enforced shut down of the furnaces of the Mahoning Valley and other points for the want of fuel held over at the mines or blocked on the way sidings, the long continued delays of merchants and manufacturers in securing needed supplies or making shipment of goods sold, it is manifest that if Pittsburg is to grow in the ratio of the past, existing shipping facilities must at least be duplicated. Neither city nor commerce can continue to grow under conditions which now exist and have existed for months. More railroads must enter the city, must be encouraged instead of being embarassed by obstacles interposed by councils or existing railway corporations. In view of the natural difficulties of hill and valley to be overcome by new railroads seeking entrance it is conspicuously evident that Pittsburg's rail possibilities are quite limited evenon the presumption that it is possible to secure wise and patriotic councils, and railway corporations be so divested of selfishness that they will cease to say to new comers, "thus far and no farther." Still the natural environment of our city will necessarily limit to some extent the enlargement of railway facilities, what then? Is our city doomed to halt in the race for industrial supremacy? Not necessarily, our rivers constitute the hope of the future. With obstructive bridge piers which limit shipping capabilities removed, navigation improved by utilizing waters passing through the city's territory, there will be no such congestion of shipment as now prevails to the serious detriment of business and city growth. It is to the credit

and honor of river men that while the great rail corporations which enter city limits have apparently combined and are using their utmost endeavorsto prevent the entrance of another railway, which would help relieve the long protracted freight congestion, river interests are extending to the new comer every possible encouragement.

Before closing we venture to present one more fact germane to the discussion, namely, the marvelous developement of the science of bridge building. In the early days of railway bridge construction across the Ohio river, it was most strenuously contended that a 300 foot railway bridge span was the utmost limit for safety, and so it came to pass that the Steubenville bridge, with a 300 foot span, against every possibile protest was built and in consequence of its limitations of navigable conditions has caused a loss to the commerce of the river of millions of dollars. But this early delusion of engineering inability has been relegated to the cemeteries of the past, and this society is on record by the admission of one of its most prominent members that safe spans of 1000 feet can be built. In his language "money can do it," but better than this admission, a great and generous railway corporation seeking entrance into this city is, of its own free will, building a bridge across the Mononagahela river with an 800 foot span reaching from shore to shore. Encroachment upon harbor and shore lines is a matter of serious complaint, causing disastrous limitations of river commerce. River harbors are the terminals of waterway transportation, and are esential for the convenience and safety of vessels and cargoes. Take for illustration the Pittsburg harbor, in which, at certain periods, there are moored from 1000 to 1500 loaded craft, freighted with about one million tons of coal, coke, iron, steel rails, and general merchandise. Such a vast tonnage frequently exposed to storm and flood, requires all possible conditions of safety, and yet shore and harbor lines have been so disregarded and encroached upon by rail and mill corporations that in times of high water

our rivers within city limits become raging and destructive torrents, their resistless force carrying away numerous crafts and the confined waters overflowing the banks and destroying shore homes and other valuable property. These deplorable harbor conditions are so extensive that great mill sites and railway tracks are located on fills along shore lines to the detriment of river terminals ; in other words, river terminals are destroyed that rail terminals may be secured.

Against this highway larceny, this wanton invasion of waterway rights, river interests have maintained a ceaseless fight, for these invading and filching forces never send flags of truce, the success of one party only creates in others a desire for like personal appropriation of portions of the public domain. Every limitation of river utilities from Pittsburg to New Orleans is a wrong to every home, every industrial interest in the Ohio and Mississippi valleys. When the limited possibilities of rail commerce awakens the dreaming sleepers of our city to the startling fact that our rivers are our only sufficient guarantee of the future, the only and last resort for such an extension of shipping facilities commensurate with the colossal demands which are coming and will continue to come with increasing volume when the completion of the inter-ocean canal links the Monongahela and Ohio rivers to an unbroken waterway to the worlds markets ; when business eyes open, then this war upon individual and national rights and privileges will cease.

In closing I submit that in view of existing freight congestions, the confessed inability of railway management to afford relief, that it would be the crowning act of human folly to allow bridge and other corporations to continue the limitation of the shipping facilities of our rivers and the consequent limitation of the city's growth and prosperity.

ALLEGHENY TRACK ELEVATION.

MR. H. S. WILGUS,
Engineer in Charge of Work.

With only two tracks to handle the local passenger traffic out of the Federal Street Station, Allegheny, the heavy through passenger and freight traffic from Pittsburg, the West Penn through freight and local freight for the depots in Pittsburg, and at the same time contending with the heavy travel on the Allegheny streets, operation of trains has not only been slow but dangerous. Across Marion avenue there have been as high as 450 train movements in one day. With a 27-lever machine (44 throws) at this point to govern signals and interlocking, there were recorded in one day 3,403 lever throws; since then this number has been greatly increased.

To take care of this constantly increasing traffic and to eliminate grade crossings, the elevation of the tracks has become a necessity.

The first step in this direction was the building on a high level of the Union Station, Pittsburg. This gives in Pittsburg overhead crossings at Liberty avenue, Eleventh street and Penn avenue, three streets constantly congested with street traffic, and overhead crossings through Allegheny.

The general plan of work is as follows:

The track elevation provides for four tracks, with the exception of a short distance from the Union Station to the river bridge, where there are two. The new river bridge provides for four tracks, two each on the high and low level. These two levels meet at Anderson street, Allegheny, and continue from there west on the same level. The two high level tracks take care of the through freight and passenger traffic from Pittsburgh; the two low level tracks of the local Pittsburg freight business, including connections with the Allegheny Valley and Pittsburg Junction Railroads.

Thus far no definite plans have been determined upon for the West Penn passenger terminals in Allegheny. Their plans, etc., for their track elevation have not been fully developed. Temporarily their trains will stop at Chestnut street, Allegheny.

The present terminal facilities for the immense local passenger traffic out of Allegheny will be greatly improved, but the general layout of yard tracks will be about the same. The double slip switch at Marion avenue will be moved further west and a series of crossovers put in, connecting the four tracks and the one leading to the passenger yards and depot.

CURVES.

The location of the work is such as to require heavy curvature, the heaviest one being 12 degrees 44 minutes on the main track at Penn avenue, Pittsburg. Out of a total length of 7,200 feet of track, 33 per cent. is curvature. At the west end of the river bridge the tracks turn to the west on a 9-degree and 2-minute curve; at Federal street the track compounds from 3 degrees 43 minutes to 7 degrees 48 minutes. The sharpest curve is 28 degrees on the C. & P., where it passes under the Ft. Wayne tracks, east of the river bridge, in Pittsburg. A 23-degree curve on a trestle provides track facilities for the Westinghouse Manufacturing Company in Allegheny.

GRADES.

The general layout is such that heavy grades for short distances are a necessity. The high level tracks from the Union Station to the east end of the river bridge ascends on 0.491 per cent. grade. The high level tracks descend on a 0.5 per cent. grade, and the low level ascend on a 1.46 and 1.09 per cent. grade from the north end of the river bridge and terminating at Anderson street. From Anderson street west to Marion avenue the grade is minus 0.3664 per cent. The ladder and rounds at the Ft. Wayne Station, Allegheny, are all

on a 0.927 per cent. grade. The side track for the Westinghouse Manufacturing Company is a minus 2.5 per cent. grade.

Street grades are also changed. Anderson street is lowered to a 3.74 per cent. and Federal street to 0.74 per cent. The north approach of Marion avenue is a minus 8.5 per cent. grade for 240 feet, changing to 0.109 per cent. a few feet north of the bridge and continuing on that grade to Martin street.

BRIDGES.

This is a work essentially of bridges. In a total length of 6,200 feet of elevation, 40 per cent. is bridge work.

Following is a general outline of these structures:

Liberty street, two-track skew through solid floor plate girder; completed.

Eleventh street, two-track skew through solid floor plate girder, with uneven girder lengths, the larger one having one supporting column at the curb line; completed.

Penn avenue, two-track skew solid floor plate girder, with supporting columns at the curb line; completed.

Viaduct, Penn avenue to the river, Pittsburg; average height, 15 feet; average distance between bents, 35 feet; distance between columns, 18 feet. Double track. Partly built on a 12-degree 44-minute and a 2-degree 34-minute curve. Eight hundred feet long. Pedestals finished.

Duquesne way arch. Right arch 30-foot span; rises 7 feet length. One end on a false skew. Completed. Two hundred and fifty feet long.

C. & P. and P. J. R. R., three-track deck; solid floor, buckle plate construction. One-half completed.

Allegheny river bridge: Fully described by Mr. E. A. Amaden.

Viaduct at the west end of the river bridge, 180 feet long; two-track, with sidewalk below; bents, 35 feet, center to center.

At Robinson street is a 32-foot abutment, marking the

end of the viaduct and the beginning of the track elevation proper, one end of which joins onto the concrete wall, separating the high and low level tracks.

Lacock street, two brick arches, high and low level, each on a skew of 53 degrees 19 minutes.

Low level: Direct span, 40 feet; oblique span, 49.88; rise, 7 feet; radius, 32.07 feet; length, 49.57 feet; 31 stone arch ring face voussoirs, 1 foot 8 inches wide and 3 feet high. Brick lined. Corner impost stone, in rough, weighs 45,000 lbs. Now being built.

High level: Direct span, 40 feet; oblique span, 49.88; rise, 17.5 feet; radius, 21.56 feet; length, 51.12 feet; stone facing, brick interior. Work not commenced. The high level arch overlaps the low level arch four feet. An unique feature of the high level arch is the 9-degree 2-minute curve of the west face overhanging the low arch.

Anderson street, four-track, 60 feet right span; solid floor plate girder, with four pedestals at each curb line; girders 6½ feet. Foundation finished.

Sandusky street, four-track, 60 feet clear span through solid floor plate girder. The west abutment provides for three stairs, the stone steps of which rest on concrete risers. Foundation finished.

Federal street, four-track, with three wide platforms; 80 feet solid floor plate girder, with five pedestals at each curb line. The west abutment is 100 feet 6 inches west of the west street line, the interval being spanned with a viaduct. Beneath the viaduct will be located the entrance to waiting room and a sub-cellar. In the west abutment is a baggage lift for conveying baggage from the floor level to the platform for the west-bound trains on No. 4 track. Pedestals, walls and one-half of the west abutment completed.

Marion avenue sub-way, six-track, 35 feet direct span on a 46-degree 17-minute skew. Solid floor plate girder, with pedestals at the east curb line; 25-foot roadway and 10-foot

walk ; quarry faced abutment, with north wing wall 252 feet long, coping of which is on a 4.72 per cent. grade, while south wing wall coping descends on a 9.5 per cent. and the street on a 0.109 per cent. grade. East abutment and wing walls completed. In the excavation for the sub-way trouble was experienced with three or four sewers, water and gas mains.

Marburg street, 71 feet overhead foot-bridge on slight skew. Work underway.

Ridge avenue, 71 feet overhead highway on slight skew. Work not begun.

Half way between Federal street and Marion avenue is a tunnel extending from north of the tracks to midway between tracks Nos. 2 and 3, 40 feet in length and 10 feet span. At the north and south ends are baggage lifts and stairs. Foundations completed.

METHOD OF CONSTRUCTION.

At this stage of the work, three-quarters done, not a train has been delayed a single minute.

The general method has been to build the south wall and part of the abutments so as to allow the elevating of the two southmost tracks. Much cribbing and filling is going on, and trestle work, except over the cellar west of Federal street, Sandusky street and Anderson street, may be unnecessary.

From the end of the finished work at Penn avenue, Pittsburg, to the old river bridge a temporary double-track trestle, with separate lapping bents, has been built on a 2.6 per cent. grade. The separate bents are used in order that one may be torn down without disturbing the other, thus allowing the construction of one-half of the final viaduct.

Two temporary trestles have been erected over Marion avenue, one being for the Westinghouse track and the other for the dumping track. The trestle over Anderson street is so

built with pony posts and pony batter posts as to allow the erection of the girders without disturbing the trestle.

The old double lattice girder bridge over the Allegheny river was moved 43 feet at one end and 22 feet at the other on April 13, 1902. For further information see the "Railway and Engineering Review," May 3, 1902.

The old through plate girder bridge over Lacock street was changed to trestle and the old bridge taken out without delay to trains. This was done in order that the low arch might first be completed.

At Federal street temporary platforms, stairs and baggage lift will be constructed after the traffic is thrown onto the elevated tracks, Nos. 3 and 4. After tracks 3 and 4 are laid and the old track abandoned, the remainder of the work will be completed.

WALLS.

In a total length of 6,100 feet of wall, only 25 per cent is tangent, the curves ranging from 3 degrees 43 minutes to 27 degrees. The first wall built was proportioned as follows: the width of the base was made 0.4 of the height of the neat work, the top 2 feet 6 inches wide, vertical face, and rear a straight line connecting the top and bottom. Later, instead of the back being straight, it was stepped. The last method is as follows: Call the height of wall from top of foundation to under coping "h"; then width of base equals $0.45\,(h+3)$, the top remaining 2 feet 6 inches. The rear is arranged in steps 24 inches, 30 inches or 36 inches high. The thickness of wall at each step is made equal to $(h+3)$,—(height of step from base), $\times$ 0.45.

CONCRETE.

All masonry, with the exception of coping and abutments, is concrete. Because of congested traffic, lack of cars and expense in obtaining crushed stone, gravel is used for concrete work throughout. From experience with gravel concrete

in river pier foundations and core work and in retaining walls, gravel is found to give as good results as crushed stone. The company furnishes the cement. A great many brands of Portland and two of natural cement have been used with varying results. Concrete is mixed fairly wet. Too wet a mixture causes great shrinkage in the form, resulting in bad face laps. Dry concrete is better for neat work. Natural cement is used in the ratio of 1 : 2 : 5 ; Portland 1 : 3 : 6.

METHOD OF MIXING.

The sand and gravel are measured in wheelbarrows and wheeled onto the platform ; the sand and cement are spread in thin layers, one over the other, and thoroughly dry mixed, the gravel then spread over the mixture, the whole sprinkled and turned three times, shoveled into barrows or the pit, again shoveled into place and rammed.

MACHINE MIXING (CUBICAL BOX).

A box holding $1\frac{1}{4}$ yards is graduated so as to give the correct ratio between sand and gravel. Gravel and sand are shoveled into the box to their respective points, cement placed on top and the box hoisted to the top of the mixer and dumped. A barrel holding the correct amount of water is emptied into the cubical box and the box then turned 10 or 15 times and emptied into cars.

Concrete is laid in 8-inch courses. For neat work a skin of mortar, 1 : 2 Portland, is employed ; boards 8 inches high, with handles, serve for separating the concrete from the form while the skin is being placed. The form is made of 2-inch planed white pine, the rough edges being jack planed. Soft soap is applied to the face of the forms. After the forms are torn down, board-laps and other defects are removed and a coat of neat Portland wash applied.

Several forms of expansion joints have been tried. The first was tarred paper, extending through the wall every 50

feet. The second was ½-inch board running through the wall every 50 feet. The third is ½-inch board extending 2 feet into the wall, with ¼-inch cove at the angles, the idea being that the interior remains at a constant temperature, the face alone expanding and contracting. These are now being used every 25 feet and give perfect satisfaction. Four-inch tile weep holes are placed 25 feet and as near the foundation as possible. The back of the wall is graveled 18 inches wide from top to bottom.

COST.

This piece of work allows a good comparison between machine and hand-mixed concrete. One contractor uses the cubical box mixer exclusively, while the other uses the hand-mixed concrete exclusively.

COST OF MIXING.

HAND.

1 foreman	at 3.00, ½	1.50
3 men wheeling barrows	at 1.50	4.50
10 " " G. S. & C	at 1.50	15.00
3 " mixing sand and G	at 1.50	4.50
6 " " concrete	at 1.50	9.00
1 " sprinkling	at 1.50	1.50
		$36.00

Number yards per day, 60.
Cost per yard, 60c.

MIXER.

1 foreman		3.50
1 stationary engineer		3.00
1 fireman	at 1.75, ½	.87
15 men loading buckets with raw material	at 1.50	22.50
2 men dumping buckets of raw material	at 1.75	3.50
2 Tagmen	at 2.00, ½	2.00
1 man at trap door	at 2.00, ½	1.00
		$36.37

Number yards mixed per day, 100.
Cost per yard, 36c.

COST OF PLACING CONCRETE IN FORMS ABOVE FOUNDATION.

By Hand (Barrows) below 12 feet.

4 men loading concrete	at 1.50	6.00
1 foreman	at 3.00, ½	1.50
10 men wheeling	at 1.50	15.00
1 man scraping barrows		1.50
2 men placing concrete		3.00
1 man placing skin		1.50
2 men mixing and carrying mortar		3.00
Number of yards per day, 60.		$31.50

Cost per yard, 53c.
(Work above 12 feet costs a little more.)

By cars and derricks, any height.

1 horse and driver		3.00
2 men dumping concrete	at 1.50, ½	1.50
1 fireman	at 1.75, ½	.88
3 tagmen		4.50
8 men placing and ramming concrete		12.00
2 men mixing skin 2 " placing " 2 " carrying "	at 1.50	9.00
1 foreman		3.00
1 stationary engineer		3.00
2 men attaching hook		3.00
Number yards per day, 100.		$39.88

Cost per yard, 40c.

FOUNDATION CONCRETE.

Hand Mixed.

1 foreman	at $3.00, ½	$ 1.50
4 men shoveling concrete		6.00
1 man placing concrete		1.50
1 man ramming concrete		1.50
Number of yards, 60.		$10.50

Cost per yard, 17c.

Machine Mixed.

1 horse and driver		$ 3.00
3 men pushing car and unloading	at $1.50	4.50
5 men placing and ramming		7.50
1 foreman		3.00
2 men dumping mixer		3.00
Number of yards, 100.		$21.00

Cost per yard, 21c.

TOTAL COST OF CONCRETE.

IN FORMS ABOVE FOUNDATION.

HAND.		MACHINE.
$ .60	Cost of mixing	$ .36
.53	Cost of placing	.40
$1.13	Total	$ .76

FOUNDATION CONCRETE.

HAND.		MACHINE.
$ .60	Cost of mixing	$ .36
.17	Cost of placing	.21
$ .77	Total	$ .57

For foundation work, the placing of concrete by hand mixing is cheaper than machine mixed, for the reason that the mixing platform is placed astride the pit, and the concrete shoveled directly into place. On the other hand, with machine mixed means must be taken for disposing of the batches. It must also be understood that the amount of capital invested in a machine mixer (engine and boiler, hoist, concrete mixer, etc.) is about 100 per cent. greater than in hand mixing. At the same time, however, every large contractor has such machines on hand, and there is really no additional cost, except for moving, wear and tear, etc.

Work was begun on the Allegheny track elevation in the fore part of 1902; the work is now three-fourths completed. The date of completion is entirely problematical; many delays of various kinds greatly hinder the progress. If the work could be energetically prosecuted from now on, it could be completed in the coming early spring. Contemplated changes may defer the date of completion several months.

WRITTEN CONTRIBUTION TO THE PROCEEDINGS.

BY THOMAS P. ROBERTS, C. E.

Pittsburg is the first great city of the world which has gotten into the predicament of being unable to spread its commercial wings comfortably; which trouble has been brought about by the environment of hills which rigidily restricts the number of railroad tracks which can be extended into the city. The railroad companies are anxiously looking along their lines inquiring how many more buildings and shops they must tear down for additional side and main tracks, and there seems to be no limit to the amount they will pay, in order to lay four main tracks with a main switching track on each side, or a six track way along our rivers and through the densely crowded manufacturing precincts. The vast expenditures they are making will no doubt enable them to meet the existing demands much better but it cannot be gainsaid that the end of possible development by this means is in sight.

In this situation of affairs any project promising relief should be welcomed not only by our shippers, but by the railroad companies as well. The stories of the "freight congestions" about Pittsburg and the furnaces in the Shenango valley closing down on account of the railways not keeping them supplied with coke, are not good things to hear said of us; yet if they are true now while a number of our furnaces are being built, and great steel works going up along our rivers, what may be the situation of our western coke customers a year or two hence with these new home demands to be supplied?

The friends of waterway transportation at this time invite the particular attention of the railroad companies and the manufacturers to the possibilities of our rivers, which, in the vicinity of Pittsburg, thanks to the wisdom and liberality of

Congress, is being put in such a state of efficiency as to promise in the near future a perennial navigation for boats of 9 feet draft capacity from 1000 to 2500 tons, if so desired.

It is not necessary to go into details of relative cost of transportation; that the river rates for short, as well as for long distances, are considerably less than the rail charges on coal and other bulky products, is well known, or should be well known.

Last winter one of the locks on the Monongahela river was closed for several weeks for repairs, during a time when the heavest ice ever known to form considerably retarded the movement of boats through the other lock which was kept open. One firm using nearly 40,000 tons of fuel per week supplied by river, feeling somewhat alarmed as to their ability to keep up the supply, appealed to the railroad companies for assistance, if needed. The firm would have liked to have arranged for at least a train load of coal per diem, but not a single car load could be promised them, owing to the "freight congestion"—or railroad dyspepsia, the result of over indulgence in freight feeding.

Last winter it was shown that it was practicable to navigate the river regularly through ice 12 inches thick, so that the danger of freeze-ups may be considered as eliminated hereafter on the Monongahela. As for "dry-ups," with the Davis Island dam converted into a permanent structure, as it should be, there would be always, say 9 to 10 feet navigation in the harbor.

I am reminded by last winter's experience with ice gorges on the Allegheny above the city limits, where at present there is no navigation, that we had a very narrow escape from a serious disaster. The danger from break-ups of the gorges is greatly increased by the number of bridge piers and low structures which span the river. Had the break-up of March last been attended by even a moderate rain storm, the temporary jamming of the ice would have created wave crests which would

have swept down the streets of the city from hill to hill, doing incalculable damage. If the Allegheny river was made navigable for even 15 to 20 miles above city, the steamers could be depended upon to break up the ice, and keep the channel open, as they do now on the Monongahela. But it cannot be too sharply emphasized that the Allegheny will not be in the proper sense a navigable stream as long as the bridges are too low for boats to pass beneath them during the winter months of comparatively high water, as well as during the low water period of summer.

It seems, therefore, in conjunction with the possibility of our rivers relieving the railroad companies of much traffic which the latter must pay very dear prices for track room to accommodate, they give promise of enlarging the territory for the building of new manufacturing establishments, and thereby furnishing more business in finished products to the railroads. In France and Germany the enlargement of the waterways has always been followed by increased earnings for the railways, and the same thing will prove true in America.

Of course, if water transportation is a good thing even for short distances about the Pittsburg harbor, it is a good thing for longer distances, even to Cairo, New Orleans and the Panama canal. I may be pardoned for saying that I have never failed to observe the unanimity of feeling in Pittsburg regarding canals at Panama, at Suez, at St. Marys Falls, but when any one suggests a canal to connect the Ohio river with Lake Erie, every one looks askance.

More money is, of course, made by charging a dollar a ton on freight from Pittsburg to the lakes by rail than would accrue to a canal, which would charge only 25 cents a ton for the same work. Perhaps the day is not far distant when the producers of freight in this district will realize the importance of giving the possibilities of waterway transportation the attention which it deserves.

It would pay our jaded hardworked railroad companies to

urge the completion of the canal to Lake Erie at the earliest possible date, provided they really are in earnest in their regard for Pittsburg's future welfare. This idea is urged seriously in belief that what the railways would lose in transportation of articles of low intrinsic value, they would more than recover in their passenger and high class freight receipts. Greater Pittsburg must cease to expand beyond the 1,000,000 mark of population, if it is to depend solely upon the railways for an outlet to the world's markets. With her waterways developed in conjunction with the railways there is no reason to doubt that some decades hence Allegheny County will embrace a population of 2,000,000, or more.

DISCUSSION.

MR. JOHNSON.—My friend Capt. Sibert intimated that he thought I had an elevated railroad somewhere up my sleeve, and I wish to disclaim any such charge. I have no knowledge of such a scheme.

Capt. Dravo in his remarks referred to the great losses sustained by the river men, every year by reason of collisions with bridge piers, but I think he largely overestimated the frequency and extent of loss by reason of this class of accidents. I recall reading in the daily papers, during the past year accounts of numerous accidents to tows, but I fail to recall that any one of them occurred from collision with bridge piers. In nearly every one they were due to the excessively large and unmanageable tows getting aground on bars or running into the bank when rounding bends.

I venture to say that all the wrecks which occur between Pittsburg and Cincinnati, by far the larger proportion occur at points where there are no bridges.

Capt. Dravo also laid great stress on the statement that boats with tows could not run these bridges at night, but had to tie up and wait for daylight. A few years ago at a hearing before the Board of U. S. Engineers, held in this city, an em-

ployee of one of the tow boats was on the witness stand and testified that his boat always tied up above the Steubenville bridge and waited until morning. Being asked "why" he answered, O, our pilot had a girl in that town and wanted to to stay all night.

Mr. Trimble.—I do not believe I have very much to add to the discussion. Not being possessed with the eloquence of Capt. Dravo, I do not think the Society at this late hour would care to hear very much from me.

Following Mr. Johnson's remarks in regard to the piers of the railroad bridges being an obstruction and the cause of accidents, I would state that at two different times during the past year accidents were caused at Davis Island Dam, and I presume on account of the dam being an obstruction to the natural waterway, as Mr. Johnson says all the accidents that occur on the river cannot be charged to the railroad bridge piers.

Mr. Atwood—I have little to add to the discussion from a railroad standpoint. Capt. Dravo's points are good. What is good for the community is good for the railroads.

Mr. Wendt—My opinion on this broad question is as follows:—

1. The industrial development of the Monongahela, Allegheny, Ohio and Beaver Valleys is proceeding at such a rate as to make it absolutely necessary to establish harbor lines throughout the entire Pittsburgh district.

2. In establishing harbor lines the Government should keep in mind that the interests of both the river and the abutting property holders should be carefully considered so that each party may derive the maximum benefit.

What I mean is this—there are certain points along the rivers where the establishment of harbor lines may absolutely prohibit that industrial development which is so necessary, especially in the case of railroads which find it necessary to build third and fourth tracks in connection with switching leads.

A proper appreciation of the interests of both the river and the railroad at these close points will, I think, result in a definition of harbor lines to the satisfaction of both parties.

3. In establishing harbor lines such a width of river should be allowed as will safely carry off the maximum amount of water during such floods as we experienced last winter.

4. Harbor lines when once established should be maintained and such a system of inspection should be inaugurated as will fully protect the interests of all parties.

5. The entire question should be approached and considered from the standpoint of the interests of the general public rather than from the standpoint of the interests of any particular class.

MR. WHITED—There is one point to which I would like to call your attention with regard to raising the bridges crossing the Allegheny River. There are in the neighborhood of 200,000 people living on the north side of that river, and in a few years there will be 200,000 more, and it seems to me that ready communication between the people on the two sides of the river should be the primary consideration. It seems strange that no means can be derived by which, whatever navigation may be required, can be carried on without hindering traffic between the two sides of the river. There are low bridges in other cities, and a very considerable traffic passes under them. Why cannot it be done as well in Pittsburg?

The traffic over the bridges is so vastly greater than that under them is or can be, that it seems to me to be of prominent importance.

There is some misunderstanding in certain quarters regarding the position of low and high water work in establishing jurisdiction over navigable waters. This is a point of the common law that was established in England where practically all navigable waters are tidal, and even there it extends only to ordinary high and low tides not to the extreme tides. The same rule applies in the case of rivers that are subject to occasional floods.

MR. DAVISON—I believe that the stern wheel boat, as used on our local rivers, is the best designed craft for the purpose. Fortunately the loaded craft goes with the flow of the stream, and the empty craft, which in weight bears but a small relation to the former, only need be towed against the current. This is an entirely different condition from what exists about lake and coast harbors, where a comparatively small tonnage per steam vessel is handled in any and all directions under the conditions of no current, except possibly that due to tides. The propelling vessel, for its weight, occupies a comparatively small space horizontally, rides deep in the water, and with a rapidly turning screw situated well under water, displays considerable power while at work. Its height out of water is small in comparison with our steam boats, and if they could be used about our harbor instead of the latter, the question of raising our bridges need not be considered. But their short length is to their great disadvantage, and while they might hold their own with the stern wheeler in towing up stream, it is not the force for towing alone that is needed for down stream work, but a boat of light draft, with a large horizontal section, that can, when tightly lashed to a large loaded fleet, act simply as the steering apparatus. That kind of a vessel can tow back about as many empty boats as it handled loaded ones down stream.

Now while I believe we have the best designed hull and machinery, I am questioning whether something could not be done in the architecture of the upper deck and the pilot houses, so that they would not take up so much room vertically. If this could be done, certainly a few feet could be saved, possibly one-half that Capt. Sibert expects to gain by raising the bridges. The smoke stacks of the boats are a separate problem and of easy solution.

As to the elevated structures referred to by the Captain, I would say that I think the business part of the city of Pittsburg should not be permitted to be invaded by elevated

structures for steam railroads, and furthermore, it is not necessary. Below Grant and Eleventh Street, the function of that part of the city is to serve as a place for the transaction of business. It is not even necessary to have large warehouses there. They can be located outside of this district and where property is cheaper and better adapted for the purpose. The large business and shopping interests are so great even now that our streets are congested beyond comfort and the expeditious moving about of the people. As our very small business district rears its skyscrapers heavenward the congestion on our narrow throughfares must be relieved by at least getting our trolley cars off them. The most practical solution of this question seems to be to elevate them. I believe much could be accomplished by a design therefore that would permit of a "two story" scheme on some of our most crowded streets. With such things as possibilities, the indiscriminate traversing of our city by steam railroads or elevated structures should not be permitted.

MR. EMIL SWENSSON—The subject of transportation, both by water and by land, within the domains of Greater Pittsburg, to me has been an interesting study for some time, and the papers to be read before the Society to-morrow night, dealing with the river part of it, will be of general interest and will call attention to our needs in this direction. I had looked forward to being present at their reading and discussion, but being suddenly called away from the city, I will have to forego the pleasure, and, in writing, contribute my mite, for the good of the cause.

Capt. Sibert, having kindly extended to me the courtesy of reading his very able paper before presentation, I am somewhat familiar with its contents, which touches upon some very vital points, relating to the industries of this district, as well as to the city itself.

In a general way, it is agreed that the bridges over the Allegheny river should be raised, but why the necessity of

raising them to such a height as the Captain indicates, I do not quite understand.

A large passenger and packet traffic will never be required on the Allegheny river, but an increase in the small packet traffic will likely occur. The important traffic, and what mainly will be needed is the carrying of bulk freight in barges for the plants, now located on its banks, and those that the future will see built along that river.

For the handling of bulk freight, in barges, to the plants, low and powerful tug boats, only, will be required. It is likely that such tug boats must be of the stern wheel type, but I see no reason why any other part of such boats need reach a height much greater than the wheel. Can not the river interests produce such tow boats?

The tug boats used in New York harbor for towing barges, carrying loaded freight cars, are low and powerful, taking up very little room.

I wish the Captain would explain why such high tow boats are built on these rivers? I presume they are a legacy from the past, when taking care of passenger traffic was of importance to them.

The scheme of getting down from the raised bridges over the Allegheny river to the Pittsburg streets is admirable in its conception, but, if executed, would be decidedly ugly in appearance, as well as, in a measure, ruining the present very poor and costly loading and unloading facilities of the *so called* Pittsburg wharf.

For some time I have had in mind a suggestion for a useful, and at the same time, ornamental wharf or embankment construction, between 11th street on the Allegheny river, and Smithfield street on the Monongahela river. The idea would be to build a stone wall, or quay, on the harbor line for this distance to an elevation, halfway between that of the streets, entering into Duquesne way, and that to which the Pittsburg end of the Allegheny river bridges had to be raised.

The roadway of the bridges, then, would be carried down, both ways to the adjoining streets, diagonally and on grade, being confined by tapering stone walls for the length of a block, say from Sixth street bridge to Seventh street, and from Seventh street bridge to Sixth street, intersecting halfway between said streets, at a common level, which would be the level of the quay, aforesaid. That would enable the street cars to run from the raised bridge to the level of the streets by the detour of only one block. The teams could travel the same routes or turn at the common elevation points, half way in the block, and come back on the street opposite its bridge.

These diagonal roadways could be so located that outside of them would be an embankment of sufficient width to turn teams around when delivering and receiving their loads, to and from boats, moored along the quay, the loading and unloading being done by cranes erected near the edge of the embankment.

The quay could also have recesses with steps in them and floats below, such steps and floats giving facilities for smaller craft, at any stage of water.

Foot and passenger traffic could be taken care of by masonry steps, located in direct line of the sidewalks of the streets and their bridges, and between said steps, in line of the roadway, fountains could be erected. The spaces between the upper and lower half of the inclined diagonal roadways could be beautified with trees and shrubbery, and serve as resting places for the people.

Such arrangement would be useful to the river traffic by giving increased headroom under the bridges, and to the loading and unloading of the river crafts by economy in the handling of the freight and avoiding the extra teams, now used to pull up the loads on the present steep wharf, in a measure protect the city in time of flood, and would also be attractive as a breathing place for the inhabitants of the downtown district.

This scheme, of course, does not permit the building of railroad tracks along the river front, but such tracks would be

of no special benefit to the city of Pittsburg in its present development, but rather an obstruction and eyesore. The downtown section of Pittsburg, and its business, has outgrown any freight track or freight station, as well as any mill or heavy manufacturing plant being located below 10th and Grant streets. This section should be given over entirely to offices, stores and light manufacturing.

For the economical distribution of local railroad freight, it is suggested that a union freight station, built on the present Ft. Wayne property, between 10th and 11th streets, and between the river and Penn avenue, which, if necessity required, could could be continued up to 12th street, would best serve the purpose. Such freight station to be of modern design, with rail road cars coming in on the second floor, and teams delivering and receiving their loads on the ground floor, the stories above the second being used for storage of freight, etc.

Capt. Sibert—In answer to Mr. Swensson's question as why towboats are so high, and as to why strong tug boats such as are used in New York would not do in Pittsburg Harbor, I will say:—

1st. That an assumption that only towboats are needed in the Allegheny River is not fair to the people of the Allegheny Valley. Packet boats supply the daily wants of the small shippers and the daily wants of all shippers in perishable goods, or goods in small lots, and accommodate many passengers. Freight transportation by packet within a distance of a hundred miles is much quicker than by rail. Freight delivered on the wharfboat at 2 P. M., is delivered in Morgantown, 102 miles distant, by 9 or 10 o'clock next morning. It ordinarily takes about one week to transfer the same freight by rail. This rule is also true for much longer distances, and no reason is seen why the shipping facilities of the Allegheny Valley should be limited. The Allegheny River extends above Pittsburg.

2nd. The tug boats used in New York harbor are screw propellors, and the fact that such a boat can not steer well

Prof. Fessenden, former Secretary, was called upon and responded by expressing his gratification at being able to attend, and in finding the surroundings so much improved and the Society in so prosperous a condition.

On motion the meeting adjourned at 10:55 o'clock.

CHARLES W. RIDINGER,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held in the rooms of the Society's house, Sept. 25, 1902, the chairman, Dr. Stahl, presiding. In the absence of the Secretary no minutes of the last meeting were read, and Mr. G. O. Leoffler was appointed Secretary pro tem.

Upon motion, Mr. McKenna was requested to prepare a paper on "The successive use of the Copper Potassa Chlorid Solution in dissolving samples for carbon combustions in iron and steel," also one on the feasibility of determining carbon by combustion without complete solution of the sample.

After a general discussion of recent improvements in methods of chemical analysis and of recent chemical Literatune, the Section adjourned at 10:15 P. M.

G. O. LOEFFLER,
Secretary pro tem.

COMPOSITION OF BLAST FURNACE SLAGS.

BY L. BLUM.

Stahl und Eisen, No. 21, Page 1024.

If a cast iron is wanted which is to contain as much Mn as possible, besides a minimum of silicon, or in the absence of considerable quantities of manganese in the burden, to contain as little sulphur as possible, the first condition for producing such kind of iron will be, that the slag contain a certain excess of lime. This excess of lime decreases the reduction of Si and favors that of the Mn, or on the other hand, binds the greater part of the sulphur in the burden as Ca S in the slag. Accordingly such furnace slags are usually called "Basic".

For the calculation of the burden two methods are now generally used; the Stoichiometric, by Mrazek, based on the supposition that silica and bases combine in the slags in the proportions of their molecular weights and that the different bases can substitute each other in this proportion, and the method of Platz, according to whom there exists a constant proportion between the weights of $Si\ O_2$ and Al_2O_3 on one side and the bases of the general formula RO on the other side; this proportion can be expressed by the fraction

$$\frac{RO - \text{bases}}{SiO_2 \text{ plus } Al_2O_3} = \frac{52}{48}$$

This fraction exhibited by Platz as the mean proportion between RO bases and (SiO_2 plus Al_2O_3) for producing either gray or white pig iron, was modified by Ledebur to

$$\frac{RO \text{ bases}}{SiO_2 \text{ plus } Al_2O_3} = \frac{51}{49},$$

on account of the Ca bound to S as Ca S in the slag.

The principal difference between these two methods for calculating the burdens of blast furnaces is this: Platz believes that Al_2O_3 and SiO_2 can substitute each other, while this is discredited by Mrazek. In other words, according to Platz the $Al_2\ O_3$ in furnace slag, plays the part of an acid, while

Mrazek thinks it acts as a base. Of these two opinions, this of Mrazek is inferior to that of Platz, but there are also some objections to the latter and this is to be shown in the following lines.

The decision of the question which role the Al_2O_3 plays in furnace slags, must be based on an exact comparison of the products of one single furnace, provided, that these products are obtained under the same conditions (except the burden) and during a possible long time.

The alumina in slag from furnaces which use ores from the Minette district (Luxenburg) exclusively, vary between 16 and 20%, depending on the composition of the burden. The author is enabled by analyses to base on the above mentioned principle, a comparison of two burdens which are different in Al_2O_3; though the differences here are not as considerable as in the analyses given by Platz, yet we may obtain from them a plain answer of the question under consideration.

A certain blast furnace was producing basic iron without Mn; after it had worked a pretty long time with the same burden, the compostion of the latter was changed, so that the amount of Al_2O_3 in the slags decreased. We may take, therefore, as base of our investigation, the comparison of these two slags; the one which is higher in Al_2O_3 will be called No. "I," the lower one will be called No. "II".

A test piece was taken from every flush during one month and the combined samples were analysed every 10th day. In one month three slag analyses were thus obtained, the average composition of which was calculated.

	No. I.	No. II.
SiO_2	30.97	32.05
FeO	1.28	1.20
MnO	.49	.46
Al_2O_3	19.08	17.19
CaO	45.12	46.55
MgO	2.44	2.03
S	.98	.96

The kind of silicate formed in cinder according to Stoichiometric laws and applied by Mrazek is found as follows:

I.

			Acids Oxygen.	Basic Oxygen.
SiO_2	30.97	.53 =	16.498	
FeO	1.28	.2221		.286
MnO	.49	.2255		.110
Al_2O_3	19.08	.4696		8.960
CaO	43.41	.2856		12.398
MgO	2.44	.4000		.976
			16.498	22.730

II.

SiO_2	32.05	.5327	17.073	
FeO	1.20	.2221		.266
MnO	.46	.2255		.104
Al_2O_3	17.19	.4696		8.072
CaO	46.55	.2856		12.815
MgO	2.03	.4000		.812
			17.073	22.069

$$\text{I. } \frac{16.498}{22.730} = .726 \qquad \text{II. } \frac{17.073}{22.069} = .733$$

From the Stoichiometric standpoint, i.e. according to the law of combining proportions, No. I is a mixture of 62.2% singulo silicate with 37.8% subsilicate, and No. II a mixture of 70.7% singulo and 29.3% subsilicate; hence the slag No. I, which is higher in Al_2O_3, would have a greater basicity than the lower No. II, which, however, was not the case, as it will be seen further on, and as Platz has proved already with the aid of the analyses he published. The alumina does not substitute the lime, and the calculated basicity of No. I seems only to be greater because of the oxygen contained in the Al_2O_3 and added to the sum of basic oxygen.

We will start now from the opposite view, assuming SiO_2 and Al_2O_3 can substitute each other, or in other words,

assuming Al_2O_3 to act as an acid. The sum of SiO_2 and Al_2O_3, on one hand, and the sum of the RO bases (except the Ca which is bound to S) on the other hand, should give us then the proportion,

$$\frac{\text{RO - bases}}{SiO_2 \text{ plus } Al_2O_3} = \frac{51}{49}$$

In No. I this proportion is

$$\frac{49.6}{50.4},$$

in No. II it is

$$\frac{50.5}{49.5},$$

the latter checks better with Ledebur's average number of $\frac{51}{49}$.
Judging from Platz's point of view, the higher slag No. I should show therefore a less basic character than the lower No. II. We will have to prove how near right or wrong we are.

Furnace slags of a composition as described above are generally called "short," meaning that their variations in basicity are confined within narrow limits, therefore we better rely on the composition of the pig iron in the production of which those slags were obtained. During the time of a month, in which the observations were made, the furnace was producing white Thomas iron, free from Mn; hence its contents of Sulphur was not allowed to surmount a certain percentage, and in order to control this, every cast was sampled and analysed for sulphur; since all conditions in both cases were alike, except the difference in the Al_2O_3 in burden, the contents of sulphur in the two cast irons must enable us to judge the basicity of the respective slags.

The sulphur in the iron, produced from high alumina burden, amounted to S =.113% (average of 119 determinations). During the working with the low alumina burden, five casts were made daily in order to prevent any eruptions of the pig iron and the explosions connected with them. The average

Sulphur of these 155 casts was S =.115%. This little difference may be neglected, and we may say that we have the same amount of sulphur in both kinds of iron during the two months. The Sulphur now depending in first line on the basicity of the slags, we must conclude that the basicity of both the slags were equal, in spite of the different proportions

$$\frac{49.6}{50.4} \text{ and } \frac{50.5}{49.5}.$$

Since the compositions of both slags are nearly alike, except the amounts of alumina, we are driven to the conclusion that the alumina has neither a basic nor an acid influence on the character of the slag, *but that the alumina in furnace slags acts neutral.*

If we now neglect the Al_2O_3 contents in the slags, we get the following composition:

	No. I.	No. II.
SiO_2	38.10	38.50
FeO	1.58	1.44
MnO	.60	.59
CaO	55.51	55.92
MgO	3.00	2.44
S	1.21	1.11

$$\text{No. I. } \frac{SiO_2}{CaO} = .686 \quad \text{No. II. } \frac{SiO_2}{CaO} = .688$$

Thus the proportion between SiO_2 and CaO is the same in the two slags, and that explains that their basicities are equal, as we saw also from the amounts of sulphur in the two kinds of iron.

According to all foregoing statements the basic character of these slags depends only on the presence of a basic calcium silicate, the molecular formula of which is still to determined.

I. The high alumina slag.

.98% S, bound to Ca give 1.71% CaO, which must be subtracted from the whole amount of lime; the rest is then 43.41% CaO, bound to SiO_2.

SiO_2.....59.92 SiO_2.....30.97; 59.92 = .517 = (2)
CaO.....55.87 CaO.....43.41: 55.87 = .777 = (3.005)

Thus a calcium silicate results, formula of which will be 3 CaO. 2 SiO_2. (58.3% CaO, 41.7% SiO_2).

No. II. The low alumina slag.

.96% S ....1.68% CaO
SiO_2....32.05: 59.92 = .535 = 2
CaO....44.07: 55.87 = .803 = 3.002

The formula of the calcium silicate is again, 3 CaO. 2 SiO_2.

It appears plain from all of above data and observations, that only this sesquisilicate of calcium, can be considered as cause of the basic properties of the furnace slag, and we can draw the conclusion, that after subtracting the Ca present as Ca S. the lime and SiO_2 must be present in the proportion,

$$\frac{CaO}{SiO_2} = \frac{58.3}{41.7}$$

Platz's proportion of

$$\frac{\text{RO basis}}{SiO_2 \text{ plus } Al_2O_3}$$

is not a constant one, at any rate it varies with different contents of alumina. For instance, Platz gives this proportion as

$$\frac{48}{52}$$

for slags of a Luxemburg furnace, if working on gray iron, and as

$$\frac{48}{50}$$

if working on white iron; in other words, when the amount of alumina increases, the factor decreases and vice versa. The fraction increases likewise when the furnace is working cold, so that large amounts of iron and Mn go into the slag; in this case too, the factor grows larger without the slag becoming more basic in the sense above mentioned. Is it now permitted to take off lime from the burden in order to get the right proportion

$$\frac{51}{49}$$

again? No, for in most of the cases the composition of the pig iron would be changed then; if, however, the calculation of the burden is based on the calcium silicate 3 CaO—2 SiO_2, the proportion

$$\frac{CaO}{SiO_2}$$

will not be changed, even when FeO and MnO in the slag are increasing.

The conclusions of our investigation may be expressed in three principles.

1st. The alumina of a basic furnace slag does not influence its basic or acid qualities.

2d. The basic character of a slag depends always on a certain amount of lime, which must be high enough, even after the subtraction of that part of it which is bound to S, as to form a sesquisilicate with the SiO_2 present.

3d. The basic furnace slag must therefore be considered to be a sesqui-calc. silicate. In the sense of Ledebur's theory of solutions, a sesquisilicate in which the Al_2O_3 and all other RO-bases except CaO, are in solution as indifferent bodies.

In furnace slags which are obtained when common white iron is produced this proportion between CaO and SiO_2 does not exist: they show generally a higher SiO_2 besides a lower CaO. The following table shows the composition of a slag as obtained from working up Minette ores for puddling iron:

SiO_2	36.78
FeO	2.72
MnO	.74
Al_2O_3	19.50
CaO	37.58
MgO	2.23
S	.48

The Stoichiometric proportion between SiO_2 and CaO, is here quite different from that of basic slags: .48% S, bound to Ca 0 indicates 1.08% Ca S, corresponding to .84% CaO.

$37.58 - .84 = 36.24\%$ CaO bound to SiO_2.

SiO_2 36.78: 59.92 = .613 = 1, CaO....48.25%

CaO 36.24: 55.87 = .618 = 1.05, SiO_2....51.75%.

This compound must be written then as CaO, SiO_2, corresponding to our bi-silicate. Should the contents of CaO continue to decrease, it might be assumed that the Al_2O_3 and the RO bases lose their neutral character under the predominating influence of the SiO_2, and assume basic character in the forming of silicates.

In puddling iron slags the proportion between SiO_2 and CaO, after subtraction of the Ca bound to S. would be therefore

$$\frac{CaO}{SiO_2} = \frac{48.2}{51.8}$$

(Composition of CaO. SiO2.)

As has been intimated above and from all that has been said, a simple way of calculating the furnace burden, basing the calculation upon the proportion

$$\frac{SiO_2}{CaO}$$

has been evolved. For basic slags as obtained with Thomas or foundry iron this proportion was determined as

$$\frac{58.3\ CaO}{41.7\ SiO_2}$$

In Luxenburg and Lorraine the average Silica in slags is 31%, requiring 43.43% CaO for forming the sesquisilicate 3 CaO. 2 SiO_2; for 1% sulphur we must add 1·44% CaO more, together 44.78%, or in a round number 45%. In calculating the burden, the proportion

$$\frac{CaO}{SiO_2} = \frac{58.3}{41.7}$$

would have to be changed then to

$$\frac{CaO}{SiO_2} = \frac{45}{31}$$

on account of 1% S.

The condition the author is working under has found this

proportion to be perfectly satisfactory, as proved by an experience of several years. Variations of the amount of sulphur would require a corresponding regulation of the proportion

$$\frac{CaO}{SiO_2}$$

of course.

An example may show clearer the calculation of the burden of a furnace which is to produce Thomas iron out of Minette ores. The composition of the ores as well as the respective proportions

$$\frac{CaO}{SiO_2}$$

will be seen from the following analyses:

Minette from Belvaux.

SiO_2	14.60
Al_2O_3	6.16
CaO	6.40
MgO	.74
Mn_3O_4	.60
P	.87
Fe	38.32

6.40% CaO bind $\frac{31 \times 6.40}{45} = 4.41\%$ SiO_2.

The excess of SiO_2 will be then

$14.60 - 4.41 = 10.19\%$

We will neglect in this case the contents of Si of the pig iron; but if we want to calculate the burden for a pig iron with 2% Si, we have to calculate in this way; 38.32% Fe bind

$$\frac{2 \times 38.32}{100} = .77\% \text{ Si} = 1.64 \ SiO_2.$$

The excess of SiO_2 would be then only $14.60 - (1.64 \text{ plus } 4.41) = 8.58\%$.

Gray Minette from each.

SiO_2	8.01
Al_2O_3	5.49
CaO	19.04
MgO	.83
Mn_3O_4	.49
P	.69
Fe	38.84

8.01% SiO_2 bind $\frac{45 \times 8.01}{31} = 11.63$ CaO

Excess of lime $= 19.04 - 11.63 = 7.41\%$

Red Chalky Minette from each.

SiO_2	5.15
Al_2O_3	4.66
CaO	35.04
MgO	.43
Mn_3O_4	.18
P	.44
Fe	16.13

5.15 SiO_2 bind $\frac{45 \times 5.15}{31} = 7.48\%$ CaO.

Excess of lime = 35.04 − 7.48 = 27.56% CaO.

We may now form a burden from 50 parts of Minette from Belvaux and 50 parts of gray Minette from Esch, with addition of sufficient red chalky Minette, as to get a slag corresponding with the above said conditions:

$$SiO_2 \quad \frac{50 \times 10.19}{100} = 5.09 \text{ excess of } SiO_2\text{; required.}$$

$$\text{Lime} \quad \frac{45 \times 5.09}{31} = 7.39 \text{ lime.}$$

50 parts of gray Minette contain

available lime, ... $\frac{50 \times 7.41}{100} = 3.70$

The rest which still is to be covered is 7.39 − 3.70 = 3.69 parts lime.

$\frac{100 \times 3.69}{27.50} = 13.4$ parts of chalky Minette which we have to add.

For melting this burden, we need about 45 parts coke, with about 4.5 parts ash.

The ash SiO_2 ....50%
Al_2O_3 ....15%
CaO 20%
Fe..................10%

$$\frac{20 \times 31}{45}$$

20 parts SiO_2 bind 45 = 13.77 SiO_2; the excess of silica is then 36.23 parts. 45 parts coke contain

$$\frac{4.5 \times 36.23}{100} = 1.63 \text{ excess of } SiO_2$$

which requires

$$\frac{1.63 \times 45}{31} = 2.37 \text{ parts CaO}$$

contained in

$$\frac{2.37 \times 100}{27.50} = 8.6 \text{ parts of chalky Minette.}$$

We need therefore, 13.4 plus 8.6=22 parts of chalky Minette. The burden consists then, of

50 parts Minette from Belvaux............41%
50 parts Minette from Esch..............41%
22 parts red chalky Minette.......... ...18%

and its composition is as follows:

SiO_2	14.86
Al_2O_3	7.54
CaO	21.33
MgO	.87
Mn_3O_4	.56
Fe	38.58
P	.86

The slag which will result, must show the following composition:

SiO_2	14.86 =	32.19%
Al_2O_3	7.54 =	16.54"
CaO	21.33 =	46.77"
MgO	.87 =	1.91"
MnO	.26 =	.57"
FeO	.46 =	1.01"
S	.46 =	1.01"
	45.60	100.00

The Mn0 was assumed as to be found half in the slag, half in the iron. 1% Fe and 1% S are numbers taken from experience.

$$\frac{CaO}{SiO_2} = \frac{45}{31}$$

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ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and twenty-eight regular monthly meeting of the Engineers' Society of Pennsylvania was held in the lecture room of the Society's house, 410 Penn Ave., Pittsburg, Pa., Tuesday evening, October 21, 1902, at 8:15 o'clock. President Mr. Chas. F. Scott in the chair, and 64 members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership and present same to the Society for action.

The following new members were elected at the October meeting:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
CHARLES W. BRAY,	Chief Engineer, American Tin Plate Co., 1217 Carnegie Building, Pittsburg, Pa.	B. E. V. Luty, I. W. Frank, S. B. Ely.
FLOYD W. FREDERICK,	Draftsman, W. E. & Mfg. Co., E. Pittsburg, Pa. h. 508 Kelley Ave., Wilkinsburg, Pa.	W. Smith, C. F. Scott, C. B. Connelley.
EDWARD GARRICK,	Draftsman, W. E. & Mfg. Co., E. Pittsburg, Pa. h. 720 Shady Ave., Pittsburg, Pa.	W. Schmidt, C. F. Scott, C. B. Connelley.
CHAS. P. HIDDEN,	Mechanical Engineer, Taylor, Wilson & Co., 101 Grant Ave., Allegheny, Pa. h. 540 Neville St., Pittsburg, Pa.	J. D. Lyon, A. K. Ashworth, C. B. Connelley.
HENRY D. JAMES,	Resident Engineer, Otis Elevator Co., 541 Wood St., Pittsburg, Pa. h. Wightman St., Pittsburg, Pa.	Richard Hirsch, C. F. Scott, C. B. Connelley.

BASSET JONES, Jr.,	Manager Pittsburg Office,		C. W. Rice, C. F. Scott, Richard Hirsch.

Clark & MacMullen, Consulting Engineers,
Frick Building, Pittsburg, Pa.

ANDREW KERR,	Engineer,	J. M. Camp, J. K. Lyons, C. H. Wood.

American Bridge Co.
h. 231 Matilda St., Pittsburg, Pa.

PAUL M. LINCOLN,	Engineering Staff,	H. W. Fisher, C. F. Scott, C. W. Ridinger.

W. E. & Mfg. Co.
h. Fifth and Elysian Aves., Pittsburg, Pa.

COLIN McINNES,	Manager,	F. L. White, H. J. Glaubits, Richard Hirsch.

Anchor Engine & Machine Co., Pittsburg, Pa.
h. Bennett P. O., Pa.

JOHN D. O'BRIEN,	Manager,	C. B. Connelley, Richard Hirsch, J. M. Camp.

Columbia Fireproofing Co.,
37 King William St., London, England.

FRANK ORBIN,	Superintendent,	C. W. Ridinger, H. D. Hershey, C. F. Scott.

Bureau of Electricity, Safety Building,
431 Sixth Ave., Pittsburg, Pa.

HARRY L. PRESTON,	Civil Engineer,	E. F. Wendt, R. M. Pearce, C. W. Ridinger.

Pittsburg & Lake Erie R. R. Co.
h. 1121 Sixth Ave., Beaver Falls, Pa.

CHAS. R. RHODES,	General Superintendent,	F. L. Slocum, M. J. Dowling, H. B. Robinson.

Pittsburg Valve Foundry & Con Co.,
Twenty-sixth St. and A. V. R. R., Pittsburg, Pa.

WM. M. SIMMONS,	Manager,	S. B. Whinery, C. B. Albree, N. C. Wilson.

Central District Railway & Engineering Review,
306 Frick Building, Pittsburg, Pa.
h. 5919 Rippey St., E. E., Pittsburg, Pa.

WM. SMITH,	Master Mechanic,	E. L. Messler, T. Jones, F. S. Slocum.

Jones & Laughlin's.
h. 3233 Wilmot St., Pittsburg, Pa.

GEO. SNYDER,	Mechanical Engineer,	G. G. Crawford, W. A. Cornelius, J. M. Camp.

National Tube Co., National Dept. Tube and Pipe Mills,
McKeesport, Pa.

J. P. YOUNG,	Engineer of Construction,	S. B. Whinery, E. Yawger, W. Bradford.

Westinghouse, Church, Kerr & Co., Pittsburg, Pa.

Mr. Hirsch—I move that the Secretary be instructed to cast a ballot electing to membership the seventeen gentlemen, who have been approved by the Board of Direction.

Motion duly seconded and carried.

The President—The name of one of the members elected at the last meeting, appears on the front page of our announcement in connection with the first paper of the evening.

One thing has impressed me in connection with this paper and that is the very great variety of engineering work which is centered in this Society. Other Societies are devoted to particular lines of work, civil or mechanical, or electrical or mining engineering, but here we come together as engineers unrestricted by narrow limits and thus without a common affiliation with any one line of activity. A very great variety of engineering work is represented among our members.

One of the difficulties in conducting a Society of this character is that only a small percentage of the members are particulary qualified to appreciate an advanced paper on a particular subject, while the remainder, or possibly nine-tenths, of the members are prepared to be interested only in a general or elementary presentation of a particular techincal subject. This has both its advantages and disadvantages. Those of us who are in special lines of work, instead of having a series of papers through the year which pertains to that line alone, have an opportunity of getting in touch with other lines of work and finding out what other engineers are doing in widely different fields. If you will run over the Proceedings of this Society, for the past half-year, you will find quite a variety. There have been papers on electrical matters, papers relating to railroad work, buildings, bridges, and transportation, but this evening we have an entirely different line of work for our consideration, and one with which, I will venture to say, very few of us are familiar. I think the subject this evening from the general understanding I now have of it, is of interest, in that it shows not a fundamental, but one of the auxiliary methods

by which the efficiency of certain operations may be increased. It is, if you choose, a secondary method by which the efficiency in various lines of manufacturing work may be augmented, and it may lead to more efficient production by the use of what would otherwise be wasted by-products. I have great pleasure in introducing to the Society Mr. Henry S. Mould.

MR. MOULD—The word "briquette" is a misnomer. Briquette is properly the French word for "little brick," but we do not make little bricks, we make a variety of shapes; the name seems to have been given the process, however, prior to briquetting, in putting into brick form coal dust of some of the foreign countries, and as a result has come to be used in a broad sense.

BRIQUETTING:—ITS HISTORY, VALUE AND POSSIBILITIES IN THE IRON INDUSTRY.

BY HENRY S. MOULD.

Whenever blast furnace managers are asked about briquetting, there is a tendency to smile and edge away. It is the old story of a distaste to take any radical step in the direction of change from established customs, until someone else has proven the proposition and with it the necessity to act in order to keep up with the times If no one takes the initiative no progress is made.

But if you bring up the subject of the loss resulting from flue dust waste and the evils resulting from the use of large quantities of fine ore in the furnace, there will not be found such a willingness to smile. If the furnace manager is honest, he will acknowledge that the scarcity of lump ore and its value in comparison with Mesaba, and the consequent necessity of using the fine material in the furnace in large quantities, increases the flue dust loss and gives rise to other dangers and evils that entail, oftentimes, heavy property loss and even the loss of human life.

It is to do away with these evils as far as possible that the subject of briquetting has been investigated by myself for the last eight years. There have been many failures, with sometimes little prospect of ultimate success. As time has slipped away, the field where briquetting, if done successfully, would prove an important economic factor has opened out to vastly larger dimensions than it had eight years ago. Already the great precious metal ore smelters of the country are using briquetting machines to force their flue dust and fine ores into blocks. But the iron men have been more sceptical. The opportunities for demonstrating that the work can be success-

tons of flue dust, in order that a fair blast furnace test might be obtained.

At that time the most available machine for our purpose was what is known as an "eggette" machine, which is composed of two large rolls, each having an indentation in its face to correspond with the half of an egg shape, being so placed as to register accurately and so designed as to allow the eggette thus formed to drop on to a conveyor belt. The briquettes made with this machine for the Illinois Steel Company appeared to be satisfactory and they were used in the Union furnaces.

Fig. 1.
White Eggette Machine, showing rolls containing molds.

While the briquettes manufactured were strong enough to stand up in the furnace, there were a number of other difficulties that made further experiment necessary before a successful process could be evolved. In the first place, using the "eggette" type of press, so large a percentage of binder was necessary that the cost of the briquettes was too high. In addition to this, the machine as then constructed would not stand

operators were generally lacking in a thorough understanding of the subject.

In endeavoring to understand briquetting and before I speak of my own efforts toward success, it must be known that the conditions vary widely in different regions and with the materials that are to be put into block form. The bonding agent that can be successfully used with precious metal concentrates or flue dust from the smelters cannot be successfully used with anthracite clum, and the binder used in briquetting the latter cannot be used in briquetting iron flue dust or fine iron ores. Adjustibility of pressure is also essential as different materials require varying pressure, ranging from 2,000 to 18,000 lbs. per square inch. From this you may see that the necessity for careful and patient experiment has been almost unlimited.

My entrance into the field of briquetting was made in 1894 in the interest of a bog ore manganese deposit. I made some experiments in this direction and then my attention was attracted to the much larger field offered by iron flue dust, believing that if manganese ores could be briquetted, the flue dust could be handled in the same way. I talked the matter over with the late Mr. H. M. Curry of the Carnegie Steel Company, who said that, if such a process could be shown, the company with which he was connected would take it up: first, with a view of briquetting their flue dust and later all, or a large percentage of their fine ores.

After a year of experiment, in 1895 I invited some officials of the Illinois Steel Company and the Carnegie Steel Company to witness some tests of iron flue dust briquetting at a plant where I had installed some machinery in the city of Chicago. This demonstration was made in the presence of Mr. James Scott of the Carnegie Steel Company and Mr. C. H. Foote and Mr. C. L. Miller of the Illinois Steel Company. The results of the test were such that an arrangement was made with the Illinois Steel Company whereby we were to briquette for them 1,500

nized the value of the new machine and took all of them that the manufacturers could produce.

However, the endeavor to settle once for all the problem of flue dust briquetting was not ended. It was realized that the solution of this problem was much more difficult than that of the handling of fines at precious metal smelting works. One main reason for this is the fact that the tiny particles of iron flue dust, as they are whirled about by the blast are rounded until each particle, when seen through the microscope, appears as round as a marble. In addition to this, each little piece of ore is covered with a greasy carbon coating which seems to counteract the effect of a binder. For these reasons it has been difficult to find a binder that would give a briquette with all the conditions we were looking for. The difficulties may, perhaps, be better realized when it is known that the requirements call for a briquette that shall be hard and durable; waterproof; low in moisture; able to stand long transportation in open cars; not unduly refractory or liable to decrepitate or become dust again; and the binding agent must not injure either the lining of the furnace or the quality of the iron produced. The briquettes must be produced within a reasonable length of time and the operation must be automatic, in that the material must not be handled from the time it leaves the dust bins until the finished briquette is produced. Moreover, with all of this, the cost must be moderate in order that there shall be practically no additional charge of expense to the furnace burden.

The experiments with the White Mineral Press clearly showed that the machine was impracticable for the briquetting of iron flue dust or, in fact, for the successful handling of any fine material of a gritty nature, owing to the reasons mentioned, and to the fact that not enough pressure was obtainable. The inventor and myself went to work once more to do away with the faults that we had discovered in our first combined effort. The result of this was two more machines. One of them,

known as the Improved White Mineral Press, was patented in 1898. It is a "disc" machine, built largely on the lines of the first mineral press, but with many improvements and is now, unquestionably, the best machine of this type on the market. Two of them are now operating successfully at the smelter of the Broken Hill Proprietary Company at Port Pirie, Australia.

Fig. 2.

Plan view of the original White Mineral Press, showing mold disc and pug mills.

But the main fault with both this machine and its predecessor lay in the large cost of repairs. The gritty nature of the flue dust acted as coarse sand-paper or emery on the molds and necessitated the frequent purchase of new discs. The discs could not be re-ground or renewed; it took three men

nearly half a day to replace one; a new disc weighed 1,500 lbs., was five feet in diameter, and cost about $150. This heavy repair cost feature had to be eliminated.

The second machine, patented in 1898, which we believed would do away with the faults shown by the mineral press, was an entirely new type, and was called the White Briquetting Press. Instead of a disc arrangement to carry the molds to the point where the pressure was exerted, there were six molds placed in a reciprocating press-box, into which spring and compression plungers were thrust, capable of exerting

Fig. 3.

Sectional view of No. 2 White Briquetting Press, showing position of plungers, and press box.

enormous pressure. These molds are simple in design and can be removed and replaced at a nominal cost. As they sustained all of the wear, this did away with the enormous repair cost essential where an expensive disc was used. In addition, we gained an enormous amount of pressure.

In the latter part of the year in which these two machines were brought out, a testing plant was fitted up in 32nd street,

one of the plunger type presses was installed there and the experimenting went on for three years. Binder after binder was tested and careful records of each experiment were kept. During this time, the process of briquetting in a number of fields was perfected but the successful handling of iron flue dust was still beyond our grasp.

A little over a year ago, the testing plant was shifted to the East End, where we had more room, and there a plant was fitted up, complete in every detail, with heating and drying apparatus so as to show the process of briquetting any fine

Fig. 4.

No. 1 White Briquetting Press as operated at present, showing auxiliary machinery. Capacity of this press is 100 tons in 10 hours.

material. The plunger press had been improved in many small details, although the principle of the machine remained the same. At last a binder was discovered that would hold iron flue dust, iron concentrates, or fine iron ores in hard and satisfactory briquettes, but it took 12 hours to dry them. A little more experiment and investigation and we arrived at the point where we are to-day, with a patent binder and drying apparatus that give us a continuous process for the briquettes from the

flue dust bins to the finished briquette in cars or storage bins, the whole operation taking approximately half an hour.

After telling you some of the difficulties that have been encountered in solving this problem, it is well that you should know wherein lies the value of the process in the iron and steel industry. All of you know that flue dust exists and that large quantities of it are lost to the furnace owners. All of you have probably seen that fact practically demonstrated in Pittsburg to your annoyance.

Now for a few figures. In a blast furnace producing 600 tons of iron per day, the furnace burden approximates 540 tons of coke; 375 tons of limestone; and 1,085 tons of ore; a total of approximately 2,000 tons. Assuming that the furnace managers use 80 per cent. of Mesaba ore, or 868 tons, and lose 8 % of the Mesaba burden in flue dust (and these are under the actual figures if anything), what does this mean in dollars and cents? It means that every 24 hours the furnace owners are absolutely throwing away 70 tons of ore. Estimating the value of Mesaba ore in Pittsburg at $3.50 a ton, this means that the loss in flue dust alone is $245 a day or $89,425 per year. But this is not the only loss occasioned by the flue dust. As the dust is carried through the stoves by the blast, it acts on their walls and on the boiler flues much as a sand-blast does, causing damage and wear. The heavy charge of fine ore in the furnace often causes clogging and slips, often times resulting in explosions and heavy property damage and sometimes in loss of life. The amount of loss sustained in this way cannot be estimated in dollars and cents even approximately. In addition, there is the damage to adjacent property owners and the annoyance resulting therefrom.

By the briquetting of the flue dust and the consequent reduction of the percentage of fine material used in the furnace, it could be saved to the furnace owners. Mind, I am not claiming that the briquetting of the flue dust would eliminate all of the troubles with which the blast furnace manager has to

contend at present, but that they might be materially lessened.

And this is not all. There are even greater things that can be accomplished by briquetting. In 1901, using the figures and tables compiled by the Iron Trade Review, the total shipment of ore from the Lake Superior region was 20,589,-237 tons. Of this amount, the Mesaba range contributed 9,004,-890 tons, or about 44 per cent. The amount of the total Lake Superior shipments that came to Lake Erie ports in that year was 17,014,076 tons. Of this amount, Buffalo and Erie, which are the receiving ports for ores shipped to the East, received 2,854,763 tons. The rest went to Ohio, West Virginia, and Western Pennsylvania furnaces. At a rough approximation, the Pittsburg district, including the Mahoning and Shenango valleys and Wheeling, received about 11,000,-000 tons, and it is fair to assume that the total of Mesaba ores used in this district bears the same relation to the total of all ores used, that the Mesaba output bears to the total of the Lake Superior output, namely 44 per cent. or 4,840,000 tons.

Exact and exhaustive analyses of all ore cargoes shipped from the Mesaba range show that the ores carry a heavy percentage of moisture. In 1901, from a tabulated list of these analyses compiled by the ore agents of the big steel companies, the lowest percentage of moisture shown in the Mesaba shipments was in ore from the Franklin mine and it showed 7.457 per cent. The highest percentage was in ore from the Dailey mine and amounted to 15.59 per cent, and the average amount of moisture in the Mesaba output from 52 mines for the year was 10.57 per cent. In other words, the manufacturers of iron and steel in the Pittsburg district are hauling from Lake Superior and paying freight on 511,580 tons of water. The freight rate from the Mesaba range to Pittsburg is $2.35 a ton. On this basis Pittsburg manufacturers are paying $1,202,231 a year for hauling water from the mines.

With the use of briquetting machinery, this waste in freight alone can be saved to the manufacturers, in addition to

the elimination of the other evils of which I have spoken. It is quite possible to briquette the fine ores at the mine. After first drying the material and driving off the moisture, then pressing the fine ore into blocks, the raw material can be brought direct to the furnaces in this district as lump ore in bricks that are waterproof and that are abundantly able to withstand the rough usage essential in transportation. By this means all of the evils that must now be contended with arising from the use of fine ores, can be absolutely done away with.

In this paper I have been able to give only a rough outline of this seemingly simple but really complex question. I have said nothing of the immense field for briquetting offered by coke braize, culm, slack, iron sands and a host of other materials that we have experimented with in addition to iron flue dust and fine iron ores. Suffice it to say that we have solved that problem and that the means are now at hand for the iron and steel manufacturers of this district to do away with a large number of evils with which they are now contending.

DISCUSSION.

THE PRESIDENT—The very interesting paper which has just been read is now open for discussion. There were one or two minor points in the paper which interested me considerably. For example, Mr. Mould speaks of the damage done by iron ore flue dust to "adjacent property owners and the annoyance caused thereby." I gather that some "annoyance" is caused *by* the property owners as well as *to* them. And, again, I do not know but that the fact that the manufacturers of Pittsburg are paying over a million of dollars for hauling water from the mines may account for the extensive "water" which is said to be in the stock of some of their companies.

The subject, gentlemen, is open for discussion.

MR. HIRSCH—Mr. President, I sent out a number of letters to draw out some discussions on this subject. I sent quite a great many to furnace owners and superintendents, but on the

whole received very few replies. Most of them stated they were much interested in the subject and would like to know something about it, but they did not feel prepared to take part in the discussion. I received a reply from one of our older members, Mr. Walter E. Koch, formely located here but now in the south-west (Mexico), dated Durango, Mexico, September 10th.

CONTRIBUTION TO DISCUSSION BY W. E. KOCH.

Off and on since 1876 I have been trying to find a satisfactory method of briquetting ores and flue dust, and just now I am striving in the same direction. When the flue dust is hot the best way is to frit or clinker it in a suitable furnace and return the hot clinkers to the blast furnace. If cold it is a more difficult proposition. Recently I have visited many smelters both in the United States and Mexico, and practically I see no advances over the methods in vogue twenty years ago.

The machinery is better and the fashion of briquetting is again to the front, but the briquettes are as brittle as ever and I notice many falling apart before they reached the furnace, and a large proportion broken up on charging. It seems to me there was quite half of them to make over again. During frosty weather when they freeze solid they work far better than at any other time, and though this may work in Montana, it does not in Mexico. It seems to me that lime is often a very poor binding material, and heat and pressure combined are not economical. Still I believe it is possible to produce a briquette as hard as a baked brick at a reasonable cost, but each smelterman must find a binding material suitable to his ores and dust. I have tried heat and compression, besides various kinds of binding material, but what will make a good briquette with one ore, fails completely with another. At one smelter I saw a modern machine with endless belt, delivering briquettes very fast, but quite half of them were cracked, and I feel sure more than half went back into the flues—they were a very tender lot.

The flue dust problem still awaits solution and the modern briquetting machine has but very slightly solved it.

Briquetting of ores is not new, we made tons of them in South Wales in 1875-6, until the fashion went out like crinolines and patches, and the machinery in use was just like that used nowadays. I think the first machines came from Belgium or North of France.

DISCUSSION.

MR. MOULD—It is quite true, as the gentlemen says, (referring to Mr. Koch's letter) that it is necessary to work out each problem of briquetting by itself. There is a vast difference in the ores which are to be briquetted, and what will successfully bind one will not successfully operate the other. When the improved methods of roasting ores came into vogue, that is, when the ore was crushed up fine and roasted in its fine condition, the smelters have apparently been satisfied with briquettes that certainly would not be acceptable in an iron blast furnace. The requirements are not nearly so severe in these smelters, and while it is quite true that the briquettes made with the first press we put on the market, that is, the White Mineral Press—and there are quite a number of these presses in operation—it was impossible to make briquettes that would stay together with any degree of satisfaction. Most of the smelters used simply slack lime as a binder and would take the briquettes from a carrier belt and let them dry naturally. With our later types of presses, we have been able to do very much better work using simply lime as a binder and I do not think the gentlemen (Mr. Koch) could have visited plants where out latest machines are in use, otherwise he would have seen different results. For instance, at the plant of the United Verde Copper Company—Senator Clark's company—they are making briquettes without any binder, simply relying on pressure and a silicious ore, and the briquettes are dropped seven feet from the end of the carrier belt. Even under these conditions there is apparently little breakage. With the process

we now have perfected for iron blast furnaces, and which will be available for the smelters when we can produce binders in the western country, the briquettes will be put through a tunnel dryer where they will be subject to a temperature of 500 degrees for twenty minutes, at the end of which they may be dropped 20 or 30 feet without danger of breakage. This would certainly seem to meet all the requirements of a good briquette. The Belgian process about which the gentleman speaks is one in which the eggette type of press is employed, and this machine is not available for ore briquetting unless it happens to be a very silicious or clayey ore.

A MEMBER—I noticed that Mr. Mould spoke of the interest of this subject to furnace managers, but he did not give us any idea of the actual cost of briquetting the ores. This would be quite an item in figuring the total saving. If the cost of briquetting should be at all large, it would materially reduce the saving effected.

MR. MOULD—In answer to the gentleman I would say that while we have not gotten the cost down to where we expect to be able to put it, our proposition at the present time to blast furnace owners is that we will give them a complete briquetting plant and guarantee that the cost of briquetting shall not exceed 75 cents per ton. We expect to be able to reduce that figure very considerably.

A MEMBER—I would like to ask Mr. Mould if he has ever briquetted zinc ore flue dust.

MR. MOULD—I am not quite certain on that point. We have had all sorts of fine ores and material sent to us for experimenting, but I have not kept complete run of this part of the work. I know, however, we have had more or less correspondence with the zinc ore people, but whether we have done any actual experimenting in that direction, I cannot say. We are, however, ready to experiment with any fine ore.

MR. BALTZELL—I wonder if Mr. Mould thinks briquetting the ore would reduce the fuel required in any way?

Mr. Mould—No, there is no reduction in the amount of fuel required in the furnace. All that we profess to do is to take the fine ore or flue dust and put it in the form of lump ore. There have been some experiments made with reference to mixing coke dust with ore, but they have not gone far enough to attain any definite results, and there has not been an opportunity to get any furnace tests or any other tests which would really give us a solid basis to talk about in that line.

Mr. Flanagan—Mr. Mould in referring to the word "briquette" remarked that they made various sizes and shapes. It might interest some of us to know in what sizes and shapes these briquettes are made.

He also referred to the cost of transporting the water in the ores from the mines to the furnaces. It might be of interest to state what effect the moisture in the ores has in the operation of the furnace—whether there is any marked advantage in using the briquette form of fuel in this respect.

Mr. Mould also referred repeatedly to lime as a binder and it would be of interest to know what other materials besides lime are in general use for that purpose.

Mr. Mould—The standard size of brick made at the present time is $3\frac{1}{2}''$ in diameter by about $3''$ in thickness. We can also make cylindrical shapes—with the White press they must be cylindrical—in two sizes, $3\frac{1}{2}''$ and $2''$ in diameter. We cannot make rectangular shapes to advantage.

With reference to the moisture in the ore, I am not sufficiently familiar with actual blast furnace practice to make any statement as to what essential benefit there would be in feeding furnaces with dry ore rather than with ore containing a certain amount of water. Naturally that moisture in the ore is evaporated at the top of the furnace; but whether there is a sufficient quantity of gases to do that work at practically no expense, or whether there would be a benefit by having such gas put to some useful purpose if it was not used in evaporating the water from the ore, I am unable to say. The only point I make with

reference to separating the water from the ore is this: that if it is not needed or wanted for any purpose, and if there is an average of 10% of moisture in the fine ores which could be eliminated before hauling, it certainly would save a large item in freight. I believe there is a movement on foot at the present time with reference to drying Mesaba ores, that is, taking out such moisture as can be taken out, and yet not have it so dusty that any great quantity will blow away. Some years ago there was some experimenting done by the Carnegie Steel Company, at Conneaut, in drying ores by taking all the moisture out; but there was so much loss by blowing away of the dry ore that the scheme was given up. Now my claim is that the process of briquetting will be so perfected and so cheapened that, taking the benefits which come by reason of using lump instead of fine ores, these benefits will more than compensate for the cost of briquetting, and in that way show a profit in the operation.

With reference to the binder, the almost general practice in this connection, so far as the smelter people are concerned, is the use of simply lime. We have, however, plants in operation in which molasses waste is the base, and in others dextrine is used as a base. For fuel briquetting, the general binder used in foreign countries is coal tar pitch. We have used coal tar pitch, and also petroleum residue and molasses waste, with other ingredients. The binder part of the question is to a certain extent a secret. There are many formulæ for binders which have been patented, but a composition patent is not of much strength, and I do not suppose there is a legitimate business to-day in connection with which there are so many cranks at work as on the binder proposition. We hear from people all over the world who think they have the only binder. Our testing plant is always open, however, to these people, so that their binders may be tried out, and when the actual test is made the most of them fall far short of the mark.

Mr. Glaubitz—Have you ever heard of the binding being accomplished by simply mixing with the ore some substances,

or substance, which acts chemically or through a drying effect to produce a material hard enough to be put into a furnace, without the use of mechanical pressure?

Mr. Mould—Do I understand you to mean that by simply mixing the ore and the binder, not pressing it into form at all? No, I never have heard of anything of that kind. The mechanical operation is not at all expensive, the principal cost being the cost of the binder. The automatic handling of the material and the pressing of it is so slight in its cost as not to be a figure.

The President—Does the binder increase the weight of the material?

Mr. Mould—Only to the extent to which it is added. For example, if we used 10% of binder, it would add 10% to the material.

The President—And it would cost over $1,000,000 to haul it down to Pittsburg?

Mr. Mould—I agree with you that if the binder figured out 10% of the weight of the ore, there would not be so much in saving of freight over the water. I used 10% merely to illustrate. With process as it is now, it would add about one-half of one per cent. in weight.

Mr. Lincoln—How much moisture is there left in the bricks?

Mr. Mould—They are absolutely dry. They must be after being subjected to a temperature of 500 degrees for twenty minutes.

Mr. Klindworth—I would like to ask Mr. Mould as to the cost of a plant for one furnace, say, with a capacity of 600 tons of iron daily; also the space required for such a plant?

Mr. Mould—Do you mean for a plant briquetting 600 tons per day?

Mr. Klindworth—I mean for a 600 ton furnace.

Mr. Mould—That would practically be 900 tons of ore.

The cost of such a plant would be, in round figures, about $75,000; the space required about 200″x250″.

MR. KLINDWORTH—I might also ask what the depreciation and repair accounts be each year.

MR. MOULD—That is rather a difficult question to answer, because we have no records of the repair cost for any of the plants we have in operation. We have about 48 plants with the present type of press in operation, and with two or three exceptions the parties owning these plants do their own repair work or have it done locally. About all there is to replace are the mould liners. We have no accurate data with reference to the renewal cost. It has been reported to us by some smelters as amounting to one-half cent per ton of briquettes produced. During the three years that the first presses of this type have been in operation there have been no renewals of the main parts of the machine, and the mould liners or plungers only have worn.

MR. FLANAGAN—To go back to the relative weight of the removed and the weight of the binder put in, I judge from the tenor of Mr. Mould's remarks that he would take the position that the binder put in is really useful either as a fuel or perhaps, if non-combustible, as a flux so that he would doubtless claim that the manufacturers would not be paying freight on something absolutely useless as in the case of the moisture.

THE PRESIDENT—If there are no further remarks, we will pass on to the second paper of the evening.

I called attention at the last meeting to the fact that here in Pittsburg, with its two or three rivers, we have a great many bridges; also that the bridge engineers seemed to be a very inventive class, since according to my observation there are no two bridges alike, and, moreover, when it becomes necessary to replace a bridge, we are sure to have a type differing from the original structure. The different bridges about the city which are familiar to all of us afford what might be termed a contemporaneous comparison; but we are to have this evening

a different form of comparison. We expect to go back into history a little way and learn something of the evolution of the bridges here in Pittsburg. One of the papers which formed part of the program of our last meeting was a description of the new double-deck bridge which is being constructed across the Allegheny river. The paper we have this evening could properly have been given in connection with that paper, but unfortunately was not available at that time. I take great pleasure in introducing Mr. Antes Snyder, one of our oldest members.

PENNSYLVANIA COMPANY'S BRIDGE AT ELEVENTH STREET, CROSSING THE ALLEGHENY RIVER.

BY ANTES SNYDER.

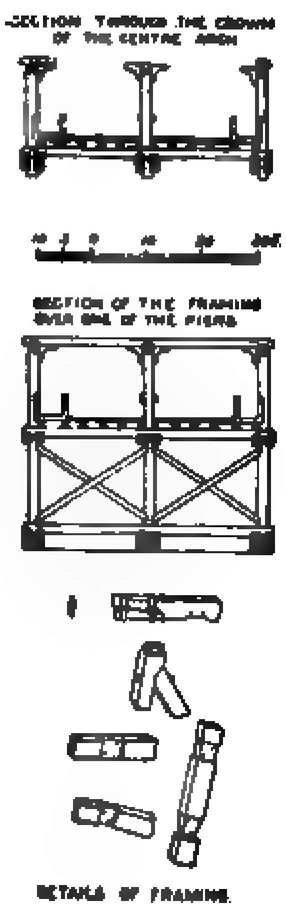
I listened with great interest to the paper, read at our September meeting, by E. A. Amaden, C. E., describing the double-deck bridge now under course of construction by the American Bridge company for the Pennsylvania lines, crossing the Allegheny river, near Eleventh street, Pittsburg, and in that connection would call your attention to that locality as being one of great interest to the profession.

It seems to me that the subject should not be dropped without a brief history of the public improvements which formerly occupied this vicinity, as I believe a little history will be acceptable to the Engineers and do us all some good. The acqueduct, which carried the Pennsylvania canal over the Allegheny river and into Pittsburg at the foot of Washington, now Eleventh, street, was immediately above this double-track bridge and within a stone's throw of its site. When Nathan P. Roberts, the engineer of the Western division of the Pennsylvania canal, which comprised the canal between Johnstown and Pittsburg, proposed, in 1827, to carry the canal over the Allegheny river at this point by a timber acqueduct, with spans of one hundred feet in length, he met with earnest opposition and plenty of ridicule. The construction of an acqueduct with such long spans was looked upon by many as impracticable, and Mr. Roberts' plans provoked very widespread and heated discussion.

The canal commissioners finally sent a commission, consisting of two of the most eminent engineers in their employ, from Philadelphia to inquire into and report upon the practicability of the construction proposed by Mr. Roberts. These engineers came to Pittsburg, examined into Mr. Roberts' plans

and reported in favor of carrying them out, and Mr. Roberts built his acqueduct. It consisted of seven spans of one hundred feet each, and cost $108,000, and was completed in 1828. It continued in use until 1843, when it was destroyed by fire. At the time of building this acqueduct there was a highway bridge extending from St. Clair street, now Sixth street, Pittsburg, across the Allegheny river to Federal street, Allegheny City, built at a cost of $100,000. There was another highway bridge extending from Smithfield street, Pittsburg, across the Monongahela river to the South Side, built at a cost of $110,000. These two highway bridges and the canal acqueduct allowed of a clearance of thirty-five feet above low water, and this seems to have been ample for the needs of navigation in the Allegheny and Monongahela rivers as it was carried on at that time. I have no doubt that the canal men, like navigators of a later date, could not see anything worthy of commendation in any system of transportation but their own, and looked upon the presence of the Allegheny river right in the path of the canal as a great obstacle to navigation. This canal acqueduct was used very generally by the public of Pittsburg and Allegheny as a means of communication, in addition to its use for the passage of boats, and for this additional use the canal commissioners collected extra tolls.

After the destruction of the Roberts acqueduct by fire in 1843 there was quite a controversy between the canal commissioners and the city of Pittsburg as to its reconstruction. I have never understood the merits of this controversy, but it resulted in the city entering into a contract with the canal commissioners by which it, the city, agreed to repair the piers and abutments and rebuild the acqueduct at their own cost and expense, and was to be allowed to collect this extra toll until they were repaid for their outlay. The city then entered into contract with John A. Roebling to repair the piers and build a wire suspension acqueduct of the same length of span as the Roberts acqueduct. This character of construction was quite



SCHUYLKILL PERMANENT BRIDGE

BUILT BY TIMOTHY PALMER, 1804

AT MARKET STREET PHILADELPHIA PA.

PLATE No. 1.

as great a novelty at that time and caused as earnest and widespread discussion as did Mr. Roberts' hundred-foot spans in 1827. Mr. Roebling, however, built his suspension acqueduct, and it did not fall down, as many doubting Thomases predicted, but continued in use by the canal until its abandonment in 1861-62, when it was torn down and removed.

I do not know the details of the construction of either the Roberts or Roebling acqueducts, but before dropping this subject, would add that the city of Pittsburg collected enough tolls to repay her outlay in rebuilding the acqueduct long before the final removal.

The original bridge of the Ohio & Pennsylvania railroad, now the Pittsburg, Fort Wayne & Chicago railway, at the point where the double-deck bridge is being built over the Allegheny river, was a Howe truss timber bridge with arches. It was built in 1857, and was a bone of contention then as now. Its construction enabled the Ohio & Pennsylvania railroad to run its trains to their Penn Street station.

For some years previous to this time Pittsburg and Allegheny, in common with other municipalities, believed in the policy of preventing the running of through trains from the east to the west and vice versa, and in carrying out this policy, which they believed to be very beneficial to their cities, did all in their power to prevent this extension of the Ohio & Pennsylvania railroad through Allegheny City and over the Allegheny river to a connection with the Pennsylvania railroad, thus continuing the transfer by omnibus and drays of passengers and freight between the Pennsylvania railroad in Pittsburg, and the Ohio and Pennsylvania railroad at Federal street in Allegheny from 1852 to 1857. This transfer employed a small army of hack drivers and draymen, who were a very important factor in the affairs of the two cities, and always took a prominent part in all processions and public demonstrations. These transfers were estimated by the engineers of the Pennsylvania railroad as equivalent to the addition of seventy-five miles to the haul be-

PLATE No. 2

tween Philadelphia and Pittsburg. The canal was at that time owned and operated by the Commonwealth of Pennsylvania, and it was only after its purchase by the Pennsylvania railroad in 1857 that the Ohio & Pennsylvania railroad, or the Pittsburg, Fort Wayne & Chicago railway, secured permission to cross the canal, which it was necessary to do in order to reach the Allegheny river. The permission of Allegheny City to cross its streets was coupled with the condition that the railroad company should construct and maintain a foot way on the upper side of the bridge to be used by the public in crossing the river free of charge. This bridge over the Allegheny river was only constructed after the Pennsylvania railroad company had subscribed for sufficient stock of the Ohio & Pennsylvania railroad to furnish the necessary funds for the same. The bridge of 1857 was replaced by a wrought iron lattice bridge in 1864, and this is to be replaced by the double-deck bridge now under way. In 1858 the Ohio & Pennsylvania railway extended its track across Penn street, Liberty street and Grant street, and into the Pennsylvania railroad station on Grant street—thus finally doing away with the vexatious and costly transfers, for while they could not, on account of the difference of gauge of one and one-half inches interchange their rolling stock, they could then transfer from car to car standing on adjoining tracks. This extension of the track over Penn and Liberty streets was very vigorously resisted by a portion of the citizens of Pittsburg. I remember when living on the banks of the Susquehanna river hearing my father read in the newspapers of the day of the great excitement in Pittsburg when this track was laid, and when I came to Pittsburg in 1863 this Penn street crossing was one of the first points I visited. This double-deck bridge now under course of construction may be considered as embodying the best practice of the bridge builders of to-day, and as illustrating how great the progress has been in these few years, I have plans of a few of the early bridges.

THE FIRST IRON BRIDGE BUILT UPON THE PENNSYLVANIA RAILROAD

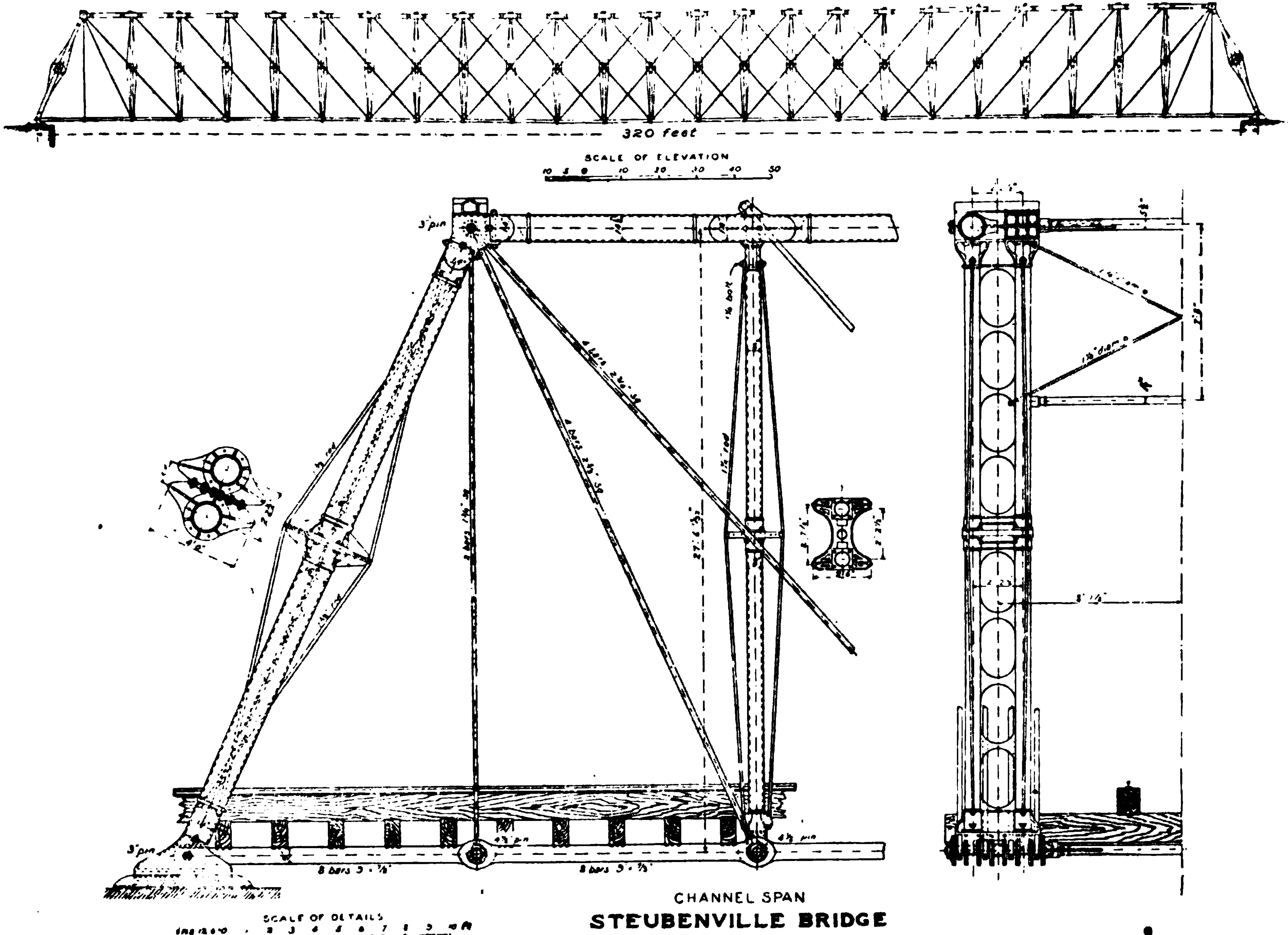
PLATE No. 3.

The first is an elevation of the permanent bridge built by Timothy Palmer in 1804 to carry Market street, Philadelphia over the Schuylkill river with a central span of two hundred and ten feet. It was framed of timber.

The second is an engraving of the timber bridge built in 1833 by the Commonwealth of Pennsylvania to carry the Philadelphia & Columbia railroad over the Schuylkill river at the foot of the Schuylkill incline plane at Peters Island near Philadelphia. It was known as the "Great American Viaduct," being 987 feet long, the longest railroad bridge in the world. It was built upon the Burr principle, and was used for both railroad and highway.

The third is a drawing of one span of the first iron bridge constructed upon the Pennsylvania railroad. This bridge consisted of five spans of seventy-five and eight-tenths feet each, and was built in 1850 to carry the Pennsylvania railroad over the Conemaugh river at Johnstown. This bridge was replaced some fifteen years later by an iron bridge of more modern design, and it in turn was replaced in 1887 by the four track stone viaduct. This iron bridge of 1850 is still in use and carries one of the streets of Jeannette over the Pennsylvania railroad.

The fourth is an elevation of a half span of the channel span of the iron bridge designed by J. H. Lenville C. E., and erected in 1863 to carry the Pan-Handle railroad over the Ohio river at Steubenville. The same construction was used in the channel span of the Pan-Handle bridge over the Monongahela river at Pittsburg and is still in use. These are but a few examples of early bridge construction, but they serve to illustrate the immense strides that have been made in that department of engineering. I have a very tender regard for the memory of these early engineers. They did not have, as we have, the experience of the past to guide them, nor the appliances that we have for carrying on the work, and in addition were compelled to educate the skilled workmen required to carry out their plans. They were men of courage and resources, such men as Nathan S. Roberts



CHANNEL SPAN

STEUBENVILLE BRIDGE

DESIGNED BY

J H Linville C. E.

BUILT 1863-64

PLATE No. 4.

Engineer of the Western division of the Pennsylvania canal, who, when he found he could not get suitable hydraulic cement for his masŏnry, built a mill at Johnstown and made his own cement, and a very good article he made, as the writer has reason to know from having torn down masonry constructed by him, or John A. Roebling, who, when he could not get wire suitable for his suspension acqueduct, had it drawn at Saxonburg in Butler County under his own supervision, and sent it by canal from Freeport to Pittsburg, and many other engineers upon these early public works, whose names and space forbid my mention. There passed away only a few weeks ago in Philadelphia, W. H. Wilson, a man who was engaged as an engineer on the construction of the Philadelphia & Columbia railroad more than 70 years ago. It seems almost beyond belief that all the development of railways, amounting to some 200,000 miles in the United States alone, has occurred during the professional life of this engineer. These early engineers received the support of many public spirited men of their day, but by the general public were looked upon as visionaries or fools.

The Pennsylvania Railroad Company was chartered to build a railroad from Harrisburg to Pittsburg. The Harrisburg, Portsmouth, Mount Joy & Lancaster Railroad Company was chartered, in 1836, to build a railroad from Harrisburg to Lancaster, there to connect with the Philadelphia & Columbia Railroad, and form the link necessary to a through railroad from Harrisburg to Philadelphia. General Simon Cameron, who, by the way, was not an engineer, was greatly interested in the building of this link, and traveled through Lancaster County holding public meetings and urging the hard-fisted farmers to subscribe to the stock of the company. At one of these meetings he became very much excited, when enlarging upon the advantages to be derived from the building of this railroad, and wound up his speech by saying that he expected to live to see the day that he could eat his breakfast in Harrisburg and his supper in

PLATE No. 5.

Philadelphia. After the meeting he met one of his hard-fisted farmer friends who remarked: "Well, Simon, it's all right for you to talk that way to the boys, it tickles them, but don't think you can get me to believe any such nonsense as that." Now General Cameron not only built his railroad, but he lived to see the day that he could take his breakfast in Pittsburg and his supper in New York City. In the summer of 1851 James Burns, State Superintendent of the Public Works of Pennsylvania tells how he met J. Edgar Thompson, Chief Engineer of the Pennsylvania Railroad, at Duncansville, and asked him how he was going to haul cars over the mountains, and he, Mr. Thompson, replied "by locomotives." Then I saw that the man was a fool; I thought I would find out how big a fool he was, so I asked him how long he expected a train to be in running from Philadelphia to Pittsburg. "Fifteen hours," he said. Then I knew the man was a howling idiot and left him. I have brought these two incidents to your notice to illustrate the hostile public opinion these early engineers had to meet and overcome. The fact was that no one, engineer or civilian, realized the grand possibilities of the development of the locomotive engine. Mr. Allen, Engineer of the South Carolina Railroad, in reporting to the Board of Directors of his company gave as one of his reasons for preferring locomotives to horses for the operation of his railroad, that, "While we could all of us judge of the probable improvement in the breed of horses, no man could put a limit to the improvement of the breed of locomotives." You will agree with me that this was very good horse sense. All this is a digression from the subject of this paper, but I cannot refrain from referring to the early engineers. They were the pioneers of our profession, and blazed out the way for us to follow—they laid the foundation for the wonderful development of this great City of Pittsburg and the great Commonwealth of Pennsylvania. They gave these a start in the march of development and progress which they have never lost. This is a large subject, and I do not pretend to attempt to do it justice.

I only refer to it now because I find it impossible to refrain from taking advantage of this opportunity to pay my tribute to the memory of these early engineers and to ask you to do the same.

DISCUSSION.

MR. YARDLEY—In connection with the feats which some of our old bridge engineers performed, I would like to tell a story which I heard at the American Society's meeting in New York by Mr. Theo. Cooper, which was a very astonishing one to me. He said that when Mr. Roebling was building the Sixth Street bridge, along in 1859, he gave a contract for some of the links to Kloman, afterwards well known as a very successful iron worker and partner of Andrew Carnegie. The story was told Mr. Cooper by Kloman himself. He said that, just as he was starting in business and had taken pains to secure this order, he was very particular that the job should be well done, and having finished up some of the links, he asked Mr. Roebling to come up and look at them. He came, inspected the links and was pleased with their appearance. Then he had Kloman put one on an anvil, and struck it with a hammer, when it flew to pieces. Kloman, astounded at this result, apologized as well as he could. "I assure you, Mr. Roebling," he said, "I have followed your directions as closely as I could. I bought the iron you specified, and have worked it as well as I know how." Mr. Roebling replied, "These bars are very satisfactory, with one little exception; you have not treated them quite right," and then he explained to this skilled iron worker a little change in the handling, which made them all right.

MR. FLANAGAN—With reference to the early troubles of some of the old bridge engineers, I am reminded of something I read a good many years ago, and I suppose that most of the members have read the same thing, and that was George Stevenson's difficulties in originating the railroad. In the very beginning there was great opposition to these roads, and it

seems to have been believed that they would kill all the crops in the country. As I recall the article now, it seems that the promoters of a project new and strange like this not only had to guarantee to do the work, but also to convince the wisacres in Parliament that the thing was going to be a success. One of the chief methods of formulating opposition to the passage of a line of railway was to set up claims for damages done to property on either side, and a very favorite claim was for what was known as "severance," namely, when the road divided a property into two parts. An example was given of some large landholder in England who had two estates. The railroad was laid out between these two properties, and in order to prevent them from running he raised a claim for damages on account of severance, and he had enough influence to divert the railroad from its original location to some distance away. Within two or three years after, however, he realized his mistake, because he built a branch line to his estates at the expense of some £160,000.

MR. SNYDER—You have all heard of the proceedings before the Parliamentary committee when Stevenson appeared before it in the interest of his road. One of the attorneys for Parliament said, "Now, Mr. Stevenson, when this traveling engine of yours is going along, suppose there was a cow on the track, would not that be a bad thing?" "Yes, sir," said Mr. Stevenson, "for the coo'."

MEMBER—There is one point which I think should be brought out in connection with this paper, and that is the difference in the modes of constructing bridges. This is well illustrated by the lattice-work bridge now being replaced by the newer type double-deck bridge. I believe the old bridge was built almost entirely at the site of the bridge, whereas the present method is to do the erecting at some bridge shop.

MR. WHITED—Can you tell us, Mr. Snyder, something about the methods of constructing the foundations for these bridges?

MR. SNYDER—I do not think I can. Those old engineers understood masonry, however, for they did some admirable work in this line. The foundations for the bridge across the Conemaugh viaduct were splendid examples of fine masonry work. This structure was washed down by the Johnstown flood. When we tore it down we found one of the abutments was on the rock and the other abutment on timber, when, if it had been carried down only eight feet more, they would have come to rock.

MR. SHALLENBERGER—Mr. Snyder and I came to Pittsburg in 1873. He has told us what happened before that date, but has hardly touched upon the interval since. I would like to know about the length of the bridge that was built across the Schuylkill river ———. We are told of a single span three hundred and forty feet long that had twenty foot rise. It was an arch, built in three courses of six inches each in height and thirteen inches wide. It had seven planks, solidly bolted together, and the truss over it was very similar to this bridge picture (referring) where the arch carried the load. (I believe Mr. Shallenberger referred to above as the Palmer bridge, S. C. McC.)

Then Mr. Snyder knows of a wooden bridge of two-hundred-and-twenty-five-foot spans, built for a railroad, and which only went out a few years ago, namely, one built on the old Western Pennsylvania on piers one hundred and ten feet high. There were a number of other similar structures, but that one was remarkable for being a two-hundred-and-twenty-five-foot clear span.

MR. WHITED—I am not capable of going into reminiscences to any extent, but I have just recently had a little experience that may be of some value and interest to the members of the society. I have had something to do with the removal of the old South Tenth Street bridge, built about 1856, spans two hundred and twenty feet center to center of piers. The piers were built on crib work, I think about three or four feet

thick, and I suppose put in with coffer dams. One of them was partially undermined by the high water, caused partly by the narrowing of the channel of the river, due to filling in of the banks, for which reason the bridge had to be removed. The masonry was very poor. The backing was a blue stone, to a large extent, and the facing but little better. The mortar—I really do not know what it was made of; it looked as if it had cement in it; there was not much left below the water line. As a whole, the bridge stood very well, except the pier which had been undermined by water. The timber was almost all as good as it ever was. On the west side, where the prevailing rains and winds come from, a few of the timbers were badly decayed, but otherwise the timbers were about as sound as they were almost fifty years ago. The iron work in this bridge had corroded some, but with the exception of some iron that passed through pieces of oak, it was not corroded to any great extent. Where the iron passed through oak, however, the corrosion had eaten almost entirely through good-sized rods. Apparently the tannic acid in the oak had corroded the iron, otherwise the rods and iron work as a whole were in good condition. In view of our experience in this connection, I would suggest that bridge engineers avoid the use of oak in connection with iron where it has to stand for any length of time.

President—In looking about the room this evening, I was struck with the large proportion of young men who are present. It is particularly appropriate that, when so many of our young men are here, we should have one of the older members of the society present a paper. I see his entrance date is away back in 1880. His history of one of the landmarks—or water-marks—of our city was very interesting. In the paper he has given us we have something of the history of transportation and the development of the commercial feature, of Pittsburg, which is one of the pressing needs now. The inadequacy of our present vastly extended railroad facilities and our waterways, emphasized by the announcement, just

to-day, of a new railway to the lakes, are all in marked contrast to the conditions in earlier times. Just to think, it is less than fifty years since two railroads, one from the West, the other to the East, were connected in Pittsburg by 'bus lines. How far are those days and those ideas from the present scope of railway traffic by the great trunk lines from the East to the West! Those were the days when this city thought it was to her interest to cultivate the support of her cab drivers, whose interests were to be considered before the advance of great transportation systems. A member suggests that other instances in which particular interests take precedence of general interests are on a par with the 'bus drivers. Then when the railroads did get together, how short-sighted were even the engineers who had built roads, for they did not match, on account of the different gauges. The history contained in this paper of early engineering progress, the developments of the ideas of the people, the enlargements which have gone on in the ideas of engineers and business men and of people at large with respect to transportation and railroads has been to me most interesting. I am sure we have all enjoyed this paper and thank Mr. Snyder heartily for his efforts in preparing it.

Mr. Snyder corrects me by stating that the differences in gauge were not due to the engineers, but to the laws of Pennsylvania and Ohio. The legislatures, presumably with the idea of maintaining the supremacy of their own states, had, in their wisdom, taken measures for keeping their railway cars at home. Such laws to-day might be considered as undue restrictions of interstate commerce. This instance brings out still more clearly the changes in the ideals as well as the methods of transportation which have taken place in the last fifty years.

Mr. Hirsch—I move a vote of thanks be extended to Mr. Mould and Mr. Snyder for the papers they have presented this evening.

Motion carried. Adjourned.

Charles W. Ridinger, *Secretary.*

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and twenty-ninth regular monthly meeting of the Engineers' Society of Western Pennsylvania, was held in the lecture room of the Society's house, 410 Penn Ave., Pittsburg, Pa., Saturday evening, Nov. 22, 1902, at 8:00 o'clock, President Mr. Chas. F. Scott in the chair, and one hundred and seventy-two members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership, and present same to the Society for action:

NAME.	OCCUPATION.	ENDORSED BY.
H. S. ANDERSON,	Mechanical Draughtsman, H. K. Porter Co. Forty-ninth street, Pittsburg, Pa.	H. W. Fisher, W. A. Bole, Richard Hirsch.
THOS. H. CLAGETT,	Chief Draughtsman, With Selwyn M. Taylor, Mining Engineer. 613 House Building, Pittsburg, Pa.	H. W. Gibson, W. E. Fohl, J. M. Camp.
CHAS. S. COOK,	District Manager, Westinghouse Electric & Mfg. Co. 207 Westinghouse Building, Pittsburg, Pa.	C. F. Scott, N. W. Storer, R. S. Feicht.
JOSEPH R. HAGUE,	Assistant to General Supt. Jones & Laughlins Steel Co. Eliza Furnace Dept., Duquesne, Pa.	E. L. Messler, M. J. Dowling, F. S. Slocum.
WM. H. HAMMON,	Assistant to General Supt. Philadelphia Co. h. 343 Melwood street, Pittsburg, Pa.	F. C. Schatz, D. Ashworth, J. M. Camp.
CHAS. C. HASTINGS,	Sales Agent, For Bethlehem Steel Co. 324 Fourth avenue, Keystone Building, Pittsburg, Pa.	S. B. Ely, H. H. Anderson, R. A. McKinney.
W. C. HOLZWORTH	Chemist at Neville Works, American Steel & Wire Co. McKees Rocks, Pa.	J. M. Camp, A. G. McKenna, C. H. Rich.

JOSHUA J. JONES, - Chief Engineer, - Henry S. Mould Co. h. South Twenty-fourth street and Carey avenue, Pittsburg, Pa.		H. S. Mould, Richard Hirsch, F. C. Phillips.
JOHN H. McDONALD, - - Supt. Steel Dept. - - of National Steel Co., Bellaire Works, Ohio. h. 4139 Harrison street, Bellaire, Ohio.		J. M. Camp, C. B. Connelley, F. C. Phillips.
WM. SIDDALL, - Master Mechanic, - at Bellaire Works National Steel Co. h. 4145 Harrison street, Bellaire, Ohio.		J. M. Camp, C. B. Connelley, Richard Hirsch.
R. H. STEVENS, - Mechanical Engineer, - Homestead Steel Works, h. Munhall, Pa.		J. M. Camp, P. T. Berg, A. C. Dinkey.
WM. D. STEVENSON, - Assistant Manager, - H. W. Johns-Manville Co. 220 First avenue, Pittsburg, Pa. h. Lang avenue and Thomas street, Pittsburg, Pa.		C. F. Scott, J. H. Nicholson. S. Diescher.

TOTAL, 12.

PRESIDENT SCOTT—We are here this evening to consider a subject somewhat different from the general order of papers which we have had during the past year. We have heretofore dealt with engineering work of various kinds about Pittsburg, and have been fortunate in having several engineers at almost every meeting to present papers on the same general subject. This evening we have a different subject for our consideration, and we are also most fortunate in having with us at this time a gentleman who is a recognized authority on that subject. When one goes through the large mills here in Pittsburg the most impressive thing is the very large way in which the work is done, the large quantities of metal handled, the many, many tons of red-hot iron which are carried by cranes, and the ease with which this vast quantity of metal is put through the rolls and treated by various processes; all this is astonishing to the observer. In marked contrast to this impression, and a fact which we hardly realize when considering the large block or mass of material, is the very close scrutiny to which it is subjected by scientific men and scientific processes. The iron is treated to obtain certain physical characteristics and to meet certain chemical requirements. We are now to have another view of the iron—its structure and molecular characteristics.

A new world is revealed. There is about as great a difference between a blind man and one with normal vision as there is between ordinary sight and that of an eye aided by a microscope. It is the use of the microscope which has revealed so much to us in other lines, such as biology, and kindred sciences, and which has been of such immense service in the world of the animate as well as in the world of the inanimate. I now have the privilege of introducing to you Professor Albert Sauveur, Manager of the Boston Testing Laboratories, who will address us upon the use of the microscope in determining the properties of steel.

THE USE OF THE MICROSCOPE IN THE DETERMINATION OF THE PROPERTIES OF STEEL.*

BY PROFESSOR ALBERT SAUVEUR.

It affords me great pleasure to be able to talk before this Society on a subject in which I am deeply interested, and to know that you also—at least to a certain extent—are interested in the same subject. The pressure upon my time has been so great that I have been prevented from preparing a formal paper, and I shall therefore be in need of your indulgence. While I am well aware that you are all interested in metallography, your presence here to-night is proof of that; I also realize that some of you, possibly many, question the practical application of the microscope to industrial lines of work. I realize further in this connection that the burden of the proof rests upon those who have made such application, and who have devoted themselves to these methods and the development of this science. I shall, therefore, in this very short talk present to you such arguments as are, at least to my mind, conclusive evidence that the science of metallography has a practical side, and probably the most satisfactory way to deal with a problem of this character will be to assume that at least some of you have not even an elementary knowledge of the subject. In doing this I shall give more unity to my talk and possibly make it more instructive to most of those present.

First of all, let us ask what is metallography, what is this new science. It is not yet defined in any of our dictionaries, at least with the meaning we give to it. To arrive at an accurate conception of what metallography is, it is well to look into the origin of this science. When Dr. Sorby, the eminent English microscopist first placed upon the stage of his microscope a piece of steel properly polished and etched, he discov-

ered that the structure of the metal was not unlike that of igneous rock; that it was made up of constituent parts which possessed all the characteristics of minerals; and just as the study of rocks brought into existence the science of petrography, so from the study of metals was developed the science of metallography. I think this explanation will at once give a fair conception of the meaning of the word.

Metallography is not, however, purely a descriptive science; if this were so its application to various lines of industrial work would be very limited. We do not deal exclusively with the description of the structure. The science has its applied side. It deals also with the relation between that structure, and the treatments to which the metal has been subjected in the process of manufacture. It also deals with the relation between the structure and its properties and especially those properties which are of interest to the engineer, and upon which the value of metals in the industrial world depends.

I wish, first, to draw your attention to what we may term descriptive metallography, necessarily confining my remarks, for want of time, to iron and steel. I shall very briefly describe the structure of iron and steel of various grades, illustrating them by means of diagrams placed on the wall. If we examine under the microscope the structure of any pure metal—no matter what metal—we find it to be made up of a great number of irregular polyhedric grains. (Fig. 1.) All pure metals have the same structure, although the size of the grains may vary from one metal to another. The size of these grains in the same metal also depends more or less upon, and varies with, the treatment to which the metal has been subjected. Generally speaking, it may be said that the higher the temperature and the slower the cooling, the larger these grains.

If now we look at the structure of pure iron (Fig. 1a.)—carbonless iron—we find that this iron is also made up of these polyhedric grains. Referring to the diagram Fig. 1a (indicating), you will note that while some of these grains are bright, others

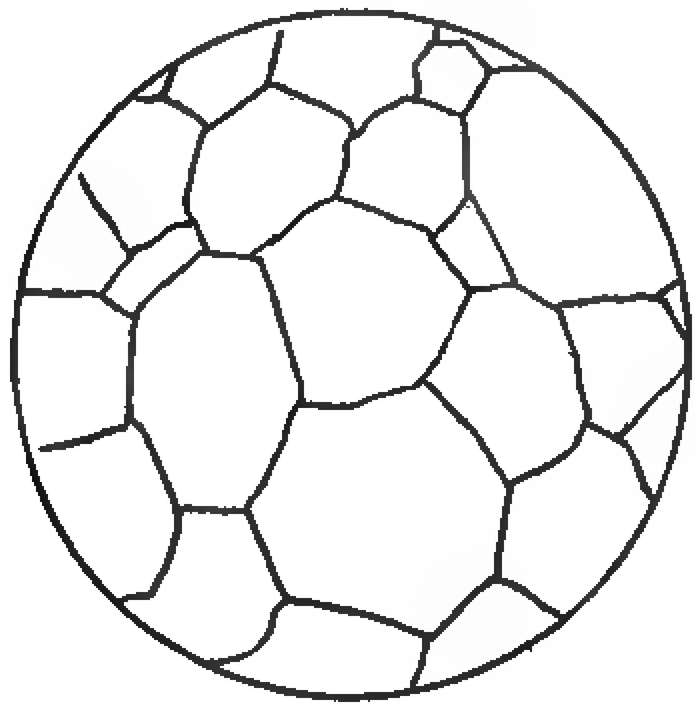


Fig. 1. Structure of Pure Gold. Magnified 100 diameters.

Fig. 1a. Carbonless Iron. Free from slag.

are dark in color, and this is due to the fact that every one of these grains is made up of a number of small cubic crystals. As we pass from one grain to another the direction or angle of these small cubes changes so that when placed under the microscope the faces of those crystals which reflect the light directly into the microscope appear white in color, while those inclined at such an angle that the faces reflect the light outside of the microscope will appear dark. This phenomenon was not originally understood, and it was some time before a satisfactory explanation was offered as to why these grains presented the appearance described.

Let us now look at the structure of industrial iron. I have here, Fig. 2 (indicating), the structure of the cross section of a piece of wrought iron. We find it is also, as we should expect, made up of a number of polyhedric grains, with very

Fig. 2. Wrought Iron, magnified 200 diameters. Cross section.

[illegible]

[illegible]

Fig. 4. Soft Steel (0.10% Carbon), magnified 164 diameters.

you will note that the structure is made up of a number of white grains, which upon higher magnification and closer examination you will find similar to those seen in pure iron, and that it also shows a number of dark particles. Since the white grains are made of pure iron, we must infer that all the carbon has segregated into these small irregular dark particles. You know, of course, that carbon in steel is present as a carbide of iron, answering to the formula, Fe_3C, but these dark particles do not consist of pure carbide, for upon magnifying to about 300 diameters, we find that every one of these dark particles is now broken up and resolved into two constituents, Fig. 4a. It would take too long to mention all the evidences we have as to the nature of the making up constituents the dark particles. These particles are made up of plates consisting alternately of pure iron, and carbide of iron. The dark constituent of the structure then is not pure carbide, but a mechanical mixture of that carbide and of iron which assumed the laminated appearance shown here. Mineralogical names have been given to those various constituents of iron. The constituent which to the exclusion of slag, constitutes the entire mass of carbonless iron

Fig. 4a. Soft Steel (0.10% Carbon), magnified 1,000 diameters.

has been called *ferrite;* the carbide of iron is called *cementite,* simply because it is very abundant in cemented steel. It is a carbide of iron answering to the formula Fe_3C. Finally the dark constituent which consists in a mechanical mixture of ferrite and cementite is called *pearlite.* This last named constituent received its name from its pearly appearance; it was first called the pearly constituent by its discoverer, Dr. Sorby. To sum up, we find in steel these three constituents: ferrite, or carbonless iron; cementite, which is a carbide of iron; and pearlite, which is a mechanical mixture of the former two.

If now we add a little more carbide to the steel, we obtain a structure like the one shown here, Fig. 5 (indicating). In this we have a larger proportion of the dark constituent, and consequently a smaller proportion of the light, which we should naturally expect. We have more carbon, therefore we have more carbide, and therefore more pearlite, and correspondingly less ferrite. If we add still more carbon, we find the proportion of pearlite still greater, as must necessarily be the case. Here, Fig. 6, we see the structure of a steel with about .5% carbon

Fig. 5. Steel (0.32% Carbon).

Fig. 6. Steel (0.52% Carbon).

[illegible]

[illegible]

[illegible]

[illegible]

cementite over the necessary amount to form pearlite, and this excess remains as such in the steel and assumes the appearance shown here (indicating). Cementite is extremely hard while ferrite is relatively very soft. Cementite always stands in relief, which is a means of distinguishing it from ferrite. The hardness of pearlite is between that of ferrite and cementite. In high carbon steel, there, we have an excess of cementite; in low carbon steel an excess of ferrite; while saturated steel is made up exclusively of pearlite.

I have some other photographs here showing perhaps more clearly the structures of various grades of steel. First, I would call your attention to these photographs, Fig. 8 (indicating),

Fig. 8. Structure of Pearlite, after a drawing by Sorly.

which show very clearly the laminated structure so characteristic of pearlite (indicating.) It is of special interest because it is an enlargement of the first drawing ever made of pearlite. It was drawn in 1886 by Dr. Sorby, and shows the structure of a steel slightly under saturation. Here (indicating) Fig. 8a and 8b, we have another drawing illustrating very clearly the structure of steel at the saturation point. Each grain as you

Fig. 8a. Structure of Granular Pearlite, after Arnold, magnified 1,000 diameters.

Fig. 8b. Structure of Lamellar Pearlite, after Arnold, magnified 1,000 diameters.

will see is a grain of pearlite, and in some of these grains the lamination is very clear and sharp, while other grains have more of a granular appearance. These changes in appearance are due to the treatment to which the metal has been subjected.

It may be said that the longer the annealing, the more marked the lamination. The pearlite of hot forged metal finished at quite a low temperature is seldom laminated.

These figures, Figs. 9, 10 and 11 (indicating), which were taken by Osmond, are magnified 1000 diameters, and show in a very satisfactory way the structure of under-saturated, saturated and over-saturated steel. This (Fig. 9)

Fig. 9. Forged Steel (0.45% Carbon), magnified 1,000 diameters.

shows a steel of about .45% carbon. Such steel should be made up of about one-half ferrite and one-half pearlite, and this is about what you see. Here, (Fig. 10) we have a structure of saturated steel, or steel nearly saturated. It is made up wholly of pearlite. Here, (Fig. 11) we have a structure of over-saluated steel containing an excess of comentite, the balance being a mass of pearlite. The excess of cementite assumes the shape of irregular plates. Figs. 12 to 16, which are reproduced from

Fig. 10. Steel (1% Carbon), polished in relief, magnified 1,000 diameters.

Fig. 11. Cemented Steel 1.5% Carbon), magnified 1,000 diameters.

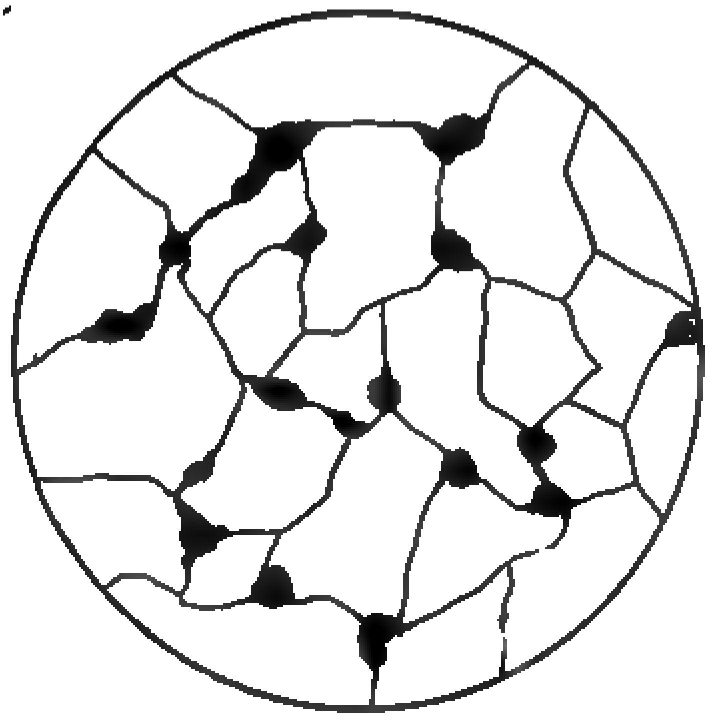


Fig. 12. Carbon 0.08 per cent.

Fig. 13. Carbon 0.28 per cent.

Fig. 14. Carbon 0.59 per cent.

Fig. 15. Carbon 0.89 per cent.

Fig. 16. Carbon 1.20 per cent.

drawings made by Professor J. O. Arnold, also illustrate in a most satisfactory manner, the relation between the carbon contents and the structure of steel.

Passing now to the structure of cast iron, I desire to call your attention to the very close analogy which I hope to be able to show you exists between the structure of cast iron and

Fig. 17. Grey Pig Iron, magnified 56 diameters.

that of steel. In the case of perfectly grey cast iron, containing practically no combined carbide, the structure is made up of a mass of carbonless iron in which may be distinguished a number of dark plates, as shown in Fig. 17, which, of course, represent graphite. It is made up of ferrite with a certain number of plates of graphite. If now we introduce a little combined carbon into the cast iron, we find that a change has taken place (Fig. 18).* We now find a number of small areas, which upon close examination will prove to be pearlite. By introducing a certain amount of combined carbon, we have simply introduced a certain amount of pearlite. By adding a little more combined carbon, the result will be that most of the metallic mass is now made up of pearlite grains, and here and there only will you see some ferrite (Fig. 19).* By still increasing the carbon a point must be reached when the metallic mass of the cast iron will be a mass of pearlite (Fig. 20).* It will be saturated just as in the case of steel. If we add still more carbon we pass the saturation point and have a structure such as is shown here in Fig. No. 21.* The white areas represent cementite, while the dark colored constituent represent pearlite. This is the structure of mottled iron. If we now look at the structure of a perfectly white iron (Fig. No. 22), which contains only combined carbon, we will find that it is merely a mass of pearlite and cementite—it is simply a high carbon steel. There is no sharp line that can be drawn between white cast iron and steel, based upon the structure, the composition, or the properties of these metals. Any demarcation we may make is purely arbitrary. This is certainly very good evidence of the close analogy which exists between these two metals. In general it may be said that our knowledge of steel can be applied to a great extent to cast iron. You frequently hear that cast iron is a very different material from steel, a much more complex substance.

*Engravings for Figs. 18, 19, 20 and 21 could not be prepared in time for the publications of this lecture.

Fig 22. White Cast Iron.

Now, I question the accuracy of that statement very much. It is not so. As soon as you introduce combined carbon into cast iron the changes which will take place in the iron matrix are exactly the same as those which will take place in the case of steel. The same characteristics appear in various grades of cast iron as in low carbon steel, medium steel, saturated steel, and over-saturated steel. I believe that if foundrymen and others interested in cast iron would look upon iron in this light, in the light of what it really is—a mass of steel, plus graphite—many of those so called mysteries, and a good many of the difficult problems they are called upon to solve, would be much nearer solution than they are at the present time.

This has been merely descriptive so far, and I now desire to call your attention to what may be called applied metallography. First let me say a few words regarding the very close analogy which exists between the structure of steel and the treatment to which it is subjected. The structure of steel is

extremely sensitive to heat treatment, or, in fact, to any treatment. A very slight change in the method of treating it will change its structure, and, therefore, its properties. At this point, let me call your attention to these (indicating) diagrams, Figs. 23 to 28, which show six different structures. I think that a layman looking at these photographs would be inclined to believe that they represent six different metals, because the structures are so dissimilar. If the samples of metal represented here be given to a chemist, he will find that they all have exactly the same composition, and, therefore, from his point of view, have the same properties, being all equally good or equally bad. If on the other hand, these samples be given to some one familiar with the microscopic examination of steel, he will at once recognize that they are from the same steel but that they have all been treated differently. He will also tell you within limits what properties to expect from these various samples, and further, what the treatments were which produced these different structures. It seems to me that this shows very plainly the limitations of chemistry. If we depend upon this science, when we come to deal with treatment, we are bound to fail. The properties of steel do not depend exclusively upon the composition. They depend upon the composition and upon the structure. The relation which exists between the structure of steel and its properties, is of a very close character. I might say upon perfectly reasonable grounds that the properties of steel — the industrial properties—depend *exclusively* upon its structure, and upon nothing else, because a perfect knowledge of the structure would imply a knowledge not only of the ultimate composition, which is all that chemistry gives us, but of the proximate composition as well. We, however, do not yet possess such a perfect knowledge, and probably never will.

Referring again to these cards (indicating) Figs. 23 to 28, first let me recall, that, other things being equal, the finer the structure, the greater the ductility of the metal. All th

the structure which is the more ductile. Fine structure, with its resulting ductility, may be obtained, then, either by hot work properly conducted or by annealing. The objection to obtaining a close structure by forging, is found in the fact that if the forged piece of metal has a relatively large cross section, while the outside of the piece would be at the proper temperature when work ceases, the mass at the center must necessarily be hotter—too hot to be finely crystalline. A very good instance of that fact is found in the case of the rail shown here, Fig. 29, where the structure of the rail at various points is indicated. The outside of the rail was, of course, finished at a much lower temperature than the center, and is, therefore, of a much finer structure. This simply illustrates the difficulty of obtaining, by mere hot work, a fine structure throughout the entire area of the cross section.

I think these few remarks must at least suggest the possibilities of metallography, but before closing I would like to answer one objection which I have often heard advanced. Many people argue that the knowledge of the structure of metals is of little importance, and that if the metal is defective, the testing machine will show it at once. To show how foolish this reasoning is, one might as well say that he does not care for a chemical analysis of steel, since if it be defective the physical test will demonstrate that fact. It is evident to any one that this is not the right view of the matter. The testing machine reveals the base fact that the metal is defective without indicating the cause, and still less suggesting a remedy. We want to know why it is defective. If it is defective we want to know whether it is due to defective composition or whether due to defective treatment, and the right structure is of just as much importance as the right composition. It is just as important to know that your steel is not of too coarse a structure, as it is to know that it does not contain too much phosphorus. The lack of ductility and the brittleness caused by a coarse crystallization is just as objectionable; it is to be

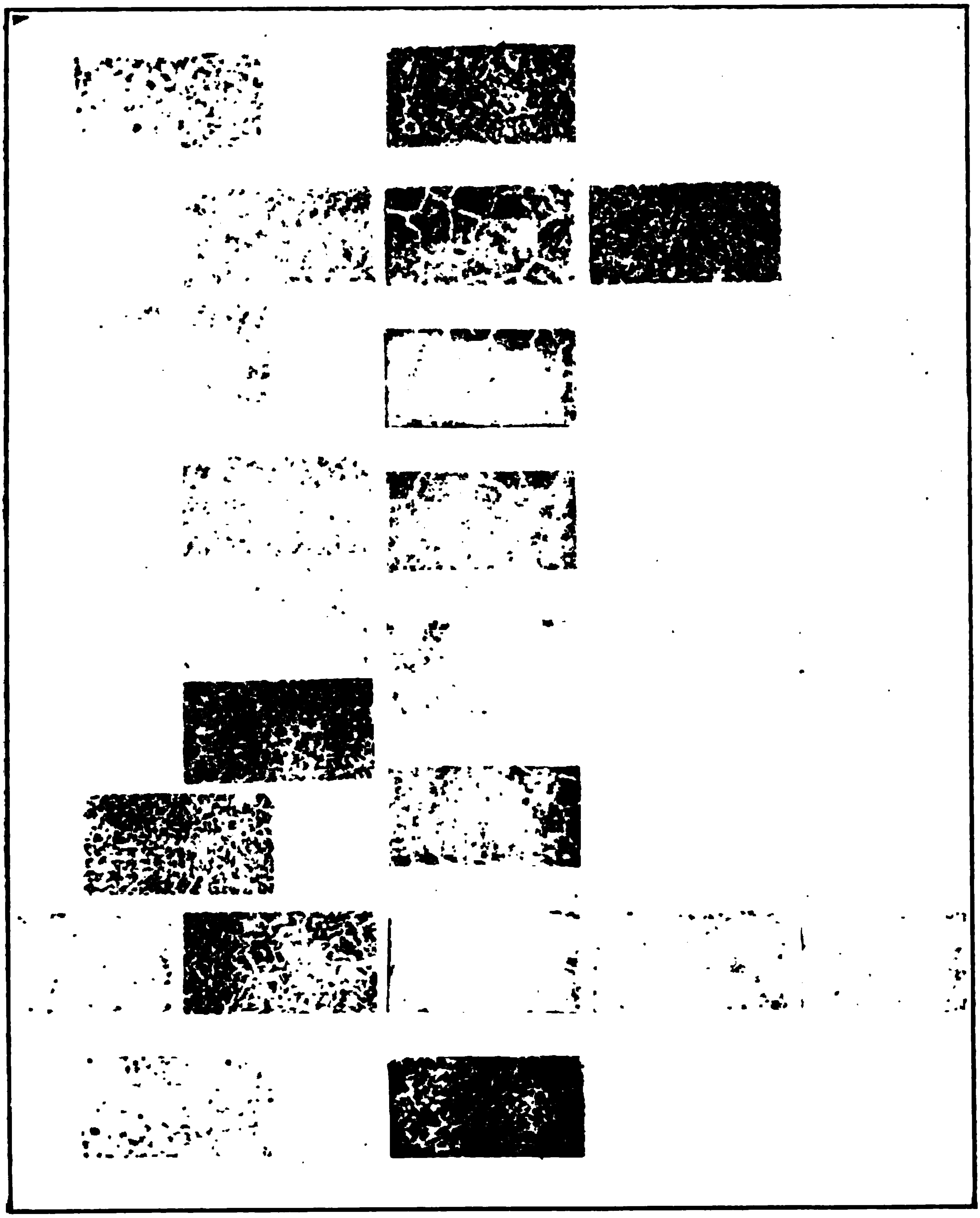
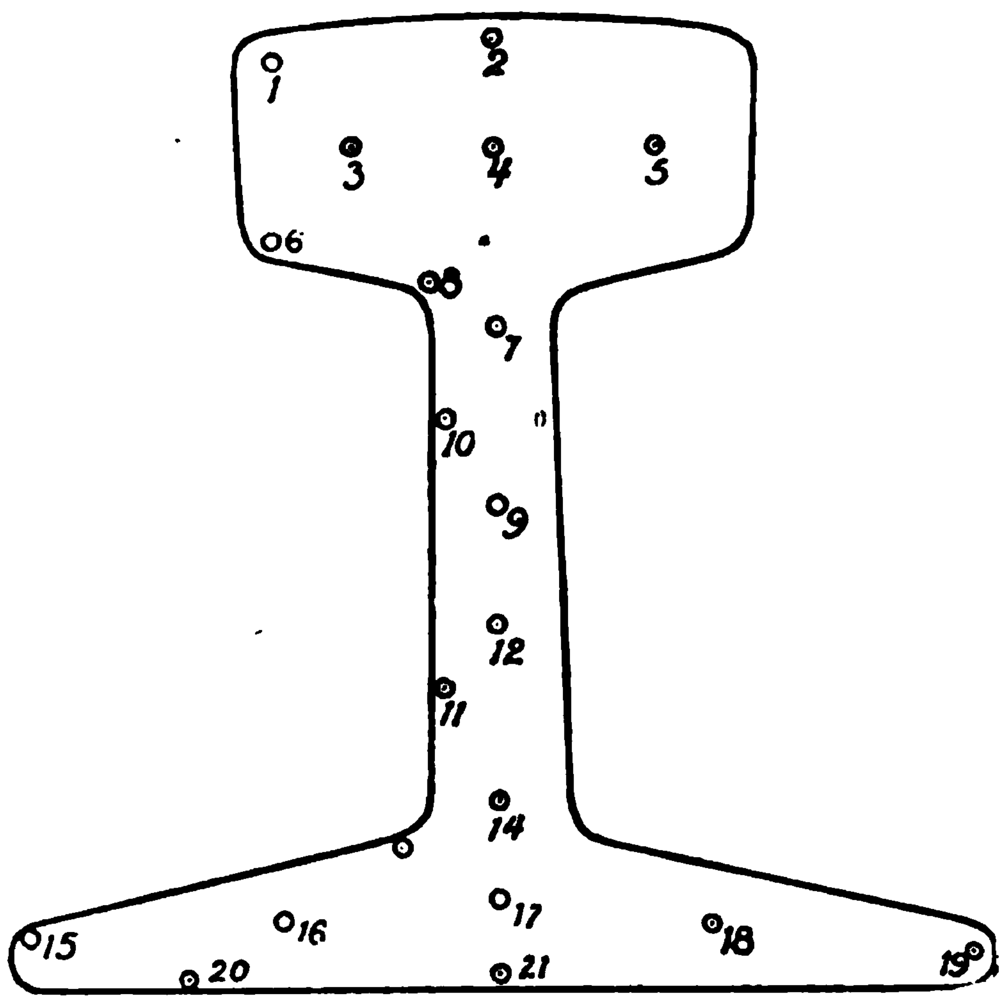


Fig. 29. Structure of various parts of the same rail section.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guarded against with as much care; as the brittleness caused by too high a percentage of phosphorus.

There is another objection which comes to my attention every once in a while. Some people make up their minds to take up metallography, and expect that it is going to solve all the troublesome problems and puzzles which they have been unable to solve, and that it is going to do it in a very few weeks, with very little effort on their part. If they are disappointed they, of course, blame the science of metallography for it. This is certainly not reasonable. I recall a case in point. You will remember how difficult it was for the chemist to get into the steel mills, and how he finally was admitted. Many of the steel makers thought their new chemist was going to solve all their difficulties at once, and when they found this was not so, there was a reaction against chemistry. As it was with chemistry, so it will be with metallography; history must repeat itself. You cannot expect metallography to settle all your troubles. It is just as uphill work in this branch of science as in any other, but, if you will take up the subject in an impartial and reasonable frame of mind, I think that very few of you will be disappointed. The time will come, indeed it is near at hand, when the microscope will be deemed of as much importance in a metallurgical laboratory as the chemical balance.

The officers of this Society have been able to collect here a few of the devices used in carrying on metallographic work. I want first to call your attention to this electric furnace. In taking up metallographic work, we very soon found that it was desirable to do a little experimenting in heating. We found that it was highly important to have a furnace in which we could obtain any desired temperature, within certain limits, and retain it. The gas furnace proved quite unsatisfactory, and many workers have turned their attention to the electric furnace. Most of these furnaces have consisted of a coil of platinum wire wound on the outside of a muffle, the current passing

through the coil and heating it to a high temperature owing to its electrical resistance. In the furnace which we have here, the heating coil is placed *within* the muffle, thus doing away with the necessity of heating through the muffle. A resistance coil of nickel wire is placed within the furnace, and by proper regulation of the resistance, we can produce and maintain any

Fig. 30. Special Microscope.

temperature between 300 deg. C. and to 1,200 deg. C. These furnaces are very useful indeed.

The other apparatus required for metallographic work is shown here. The ordinary stand is not very well adapted to metallographic work, while a stand of special construction, as shown here (Fig. 30), is most desirable. Its most important feature consists in the up and down motion of the stage by rack and pinion mechanism. The advantage of such an arrangement will be readily appreciated by those who have had any experience in the examination of opaque objects.

The special specimen-holder shown on the stage of the microscope permits to place immediately on the stage in the proper position to be examined, any polished specimen, no matter how irregular in shape, thus doing away with the necessity of preparing two exactly parallel surface, a task which is very laborious. Various sources of light may be used for the

Fig. 31. Welsbach Lamp with Condenser.

Fig. 32. Incandescent Lamp, 150 candle-power.

illumination of the object, a Welsbach lamp and condenser (Fig. 31), affords a sufficient illumination. A 150 candle power incandescent lamp (Fig. 32), also gives a good illumination. An electric arc lamp (Figs. 33 and 34), with the necessary condensing lenses and other accessories, constitutes an ideal illuminating outfit for metallographic work. It is the only source of light intense enough to throw the structure of the metallic samples directly on the screen, as I shall now try to show you.

By the addition of a few accessories, such an equipment may be converted into an excellent apparatus for lantern slide projection (Fig. 35), or for micro-slide projection (Fig. 36). The photo-micrographic camera shown here (Figs. 33 and 34), is an excellent apparatus, which may be very quickly adjusted whenever it is desired to take a photo-micrograph of the structure. This illustration (Fig. 37), shows the metallographic apparatus of the Boston Testing Laboratories.

*A stenographic report of an extemporaneous lecture.

Fig. 33. Electric Arc Lamp Illuminating Outfit.

Fig. 34. Electric Arc Lamp Illuminating Outfit.

Fig. 35. Electric Arc Lamp, with Attachment for Lantern Slide Projection.

Fig. 38. Electric Arc Lamp, with Attachment for Transparent Micro Slide Projection.

DISCUSSION.

Mr. Scott—I am sure the Professor will be very glad to answer some of the questions which are, doubtless, uppermost in your minds.

Mr. Ely—I would like to ask Professor Sauveur to tell us what kind of an appearance high phosphorus has in the structure of iron or steel?

Prof. Sauveur—It is very difficult to identify any change in structure due to the presence of phosphorus. In the case of cast iron, however, phosphorus can be detected. In steel, sulphur is sometimes found in the shape of so called sulphur flaws, and can be readily located, but it is not always so. Many times I have examined high sulphur steel which did not show these peculiar defects. There is a very interesting problem here to be worked out, viz., the effect of the presence of phosphorus and sulphur on the micro-structure.

Mr. Skinner—I would like to ask the effect of manganese in very low carbon steel, the phosphorus and sulphur also being very low—in steel of, say, .06 carbon and .30 or .40 manganese. Can that be told?

Prof. Sauveur—I do not think it can be told. I have never noted the influence of manganese on steel of this kind.

Mr. Bole—I would like to say that I am particularly interested myself in what Professor Sauveur has told us this evening, and I think it a fair statement that the results of chemical analysis and even physical tests do not always constitute a true indication of the character of the piece of steel from which the test piece or bar may have been taken. It often occurs that the test bar is taken as a proof conclusive of the quality of the steel. I think it good policy to take the position that while a correct chemical analysis may indicate that a piece of metal is all right, yet it does not prove it. The chemical composition may appear all right and the metal be relatively worse, and it is beyond question that the annealing and other kinds of treatment are of the utmost importance. Test bars

as such are good as far as they go, but a study of the structure is certainly likely to add a great deal of information regarding the mysterious happenings—the castings which break and which when analyzed are all right. The test bar attached to a sample casting may have shown good results, and still the casting will break owing to some defect in the structure wholly apart from the chemical composition. While not posing as an authority on this subject at all, it seems to me that the constituent elements of a metal such as steel or iron might be likened to the materials out of which concrete is made. A man may take the right proportions of cement, sand, stone and gravel, and might mix them properly so as to get a homogeneous mass of material which would prove very reliable. But on the other hand he may take exactly the same proportions and mix the materials so as not to secure these results, and he would get a very poor article. It seems to me there is a similarity here—a sort of analogy. I think Professor Sauveur is entirely justified in stating in his talk that people need not expect too much light or too many results from this new science, but should understand that it simply adds to the information obtained from a chemical analysis and physical tests, resulting in a far better knowledge particularly of large masses of steel or iron. I was interested in the Professor's remarks on the subject of cast iron. Ordinarily, chemists have not seemed to pay much attention to this material, apparently considering steel as a more worthy field for their operations. I believe, however, that the cast iron foundry constitutes a field which needs more of their services. As a proof, too, of the fact that you cannot always make a chemical analysis of the physical properties in cast iron, I recall statements which have been made in this room when other subjects were under discussion, where it was stated—and I suppose I myself have so stated—that they have frequently seen cast iron specimens made of metal poured from a crucible, and other cast iron specimens from an air furnace, in which there

was no difference which could be detected in the chemical composition. You could not say this iron was made in the air furnace and this in the cupola, and yet the physical properties of the two cast irons were very greatly different. I have not been able to see exactly how or why—chemical analyses have not made it clear to me—but I know the difference exists and I presume the explanation lies in the heat treatment. I hope that the Professor's talk may be properly put in shape for the Proceedings so that we may read it and ponder over it at leisure.

Mr. Scott—There are doubtless a good many gentlemen present who have been working with the microscope as amateurs who feel somewhat in the dark. We would like to hear their experiences including their troubles and the particular work they have done. Mr. Walters have you not done something in this direction?

Mr. Walters—I have not done much with this line of work, although I have done something. Everything in my experience in connection with cast iron especially bears out what the Professor has stated, viz., that we have much the same structure in steel, varying with the carbon contents. Of course, the saturation point is a little lower on account of the impurities. The structure of brass is more along the line we are working on. It would appear that metallography is going to show us a good deal there, too.

Mr. Lynch—Is the lantern fixed up so that I could throw two or three slides on the screen. I have three or four slides here showing samples with which I have made physical tests, both in tension and compression ; also chemical analyses, and I think it would be of much interest to have these thrown upon the screen, and to have the Professor give us some reasons for the curves I have.

Mr. Camp—In listening to the Professor's talk, I arrived at the conclusion that I knew more about metallography before than I do now. I think, however, that as soon as we can find

room in our shop to put this apparatus, we are going to get it. The chemical and microscopic examination should go hand in hand. We have a great many troubles that the chemist cannot solve, and I think this new science is worthy of consideration. With this new aid, if we buy metal and it fails to turn out right, we have proof which we can show the people who sold us the goods; we have a photograph which will indicate that certain heat treatment or other cause, for which we were not to blame, spoiled the material for our use, seeing which, he will be willing to pay the bill, which under present conditions he is not.

Mr. Orr—I would like to ask the Professor how these slides are prepared.

Prof. Sauveur—All these were photo-micrographs, taken in the usual way, a number of them having been enlarged to the sizes indicated. Most of them were originally magnified 50 diameters, but some of them as high as 300 diameters. (Mr. Scott suggested that Mr. Orr meant the specimens to be examined.)

These specimens are simply small pieces of the material to be examined. A very convenient size is about $\frac{1}{2}''$ square. Of course larger pieces or smaller ones could be used as well. Smaller sections require less labor to polish them.

Mr. Skinner—I believe Mr. Beck is very familiar with that particular work which we have done for a particular purpose. In our researches a very limited line of this work has been covered, and I think I will ask Mr. Beck to give a description of the method of preparing specimens.

THE PREPARATION OF SAMPLES FOR MICROSCOPIC ANALYSIS AS FOLLOWED BY THE WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY.

BY MR. W. J. BECK.

The principal work done in the microscopic study of metal has been with low carbon sheet steel (used for electrical purposes), although some attention has been given to cast iron, cast steel, cold rolled steel, and alloys of babbit and brasses.

In preparing a sample for a photograph, three distinct operations are followed.

First—Cutting and shaping of the sample.

Second—The polishing and etching of the surface to be photographed.

Third—Microscopical examination and photographing.

CUTTING AND SHAPING OF THE SAMPLE.

First—In the case of sheet steel analysis, the sheet of a known heat or lot is selected, and strips of approximately $\frac{1}{4}'' \times 1''$ are cut from the various parts of the sheet, and each is recorded, and at once stamped with a serial number. After having selected several samples, they are taken, one by one, and mounted on a small holder. This holder consists of a block of hardened steel $\frac{1}{4}'' \times \frac{1}{4}'' \times \frac{1}{2}''$ with perfectly squared sides. Over this is a small frame with internal dimensions $\frac{1}{8}'' \times \frac{1}{4}'' \times \frac{5}{16}''$, and provided with small thumb screws for fastening the samples when in position. In forming the sample on the holder, it is first clamped in the vise between the holder, and a second piece of hard steel in order to obtain a smooth surface for polishing. It is then bent down on the sides of the holder forming a U-shaped piece or sample. It is then removed from the vise, and a clamp put on, holding the sample in position with the

thumb screws. This gives a perfectly flat surface on top and bottom of the holder, and the sample need not be removed for examination under the microscope during the process of polishing and photographing.

POLISHING AND ETCHING OF THE SAMPLES.

The apparatus used for polishing samples of metal is similar to the apparatus described by Mr. Albert Sauveur, in the Metalographist of October, 1901. [This polishing machine consists of four polishing wheels mounted on a horizontal shaft and revolving in a vertical plane. The first wheel is a solid fine grain emery, approximately 8″ in diameter. The second is a metal disc covered with coarse canvass coated with an emery paste. The third and fourth are made up of a wood block, the third being covered with a good quality of billiard cloth, and coated with a white paste, consisting principally of tripoli and soap. The fourth is covered with a heavy broadcloth, for which is used a paste made of jeweler's rouge. An average of twenty samples have already been prepared without renewing the cloth on the wheel, which can be done in a very short time.]

Having mounted the sample on the holder, it is not necessary to do any filing on the surface to be polished, there being but a thin coat of oxide on the surface which can be easily removed with the emery wheel, thus giving a more true surface than that obtained by means of a file or by hand on emery cloth.

When applying the sample to the emery wheel, care is taken not to hold too long in one position, but to gradually keep changing to avoid cutting deep furroughs in the surface. One or two slight touches of the sample on the emery wheel is generally sufficient to remove the scale or oxide. It is then passed to the second wheel, and the heavy scratches removed with the emery paste. The sample is then washed thoroughly and passed to the third wheel. In most cases, and for ordinary examinations of the sample, a sufficiently good surface is obtained from this wheel. If, however, photographs are to be taken,

the sample is again thoroughly washed, then applied to the fourth wheel on which a paste made of jeweler's rouge is used with an abundant supply of water, in order that the rouge does not become hard and scratch the surface.

THE ETCHING OF THE SAMPLE.

The method followed in etching a soft steel sample is one in which it is possible to carry on the etching of several samples at one time. Various methods have been tried, but the results as thus far obtained have been with the use of a solution of diluted nitric acid. The strength of this solution is approximately one part nitric acid and twenty parts water. The time required to give a properly etched surface varies from ½ to 3 minutes, depending upon the hardness of the steel.

MICROSCOPIC EXAMINATION AND PHOTOGRAPHING OF THE SAMPLES.

Third—The apparatus used for the examination, and photographing of the samples is a Bausch & Lomb microscope with camera attachment, and fitted with apochromatic objectives with compensated eye pieces and a mechanical stage.

The light used is from a D. C. arc lamp, automatically fed, and fitted with condensers and cooling cells, giving parallel rays which are concentrated by bulls eye through a ray filter, and then thrown on the illuminator of the microscope.

In the study of the structure of the metal, the image is generally thrown on a screen, which makes it much easier to select the part desired for the photograph, and less tiresome to the eyes. Having selected the section to be photographed, the plate is exposed from one to three seconds, depending upon the surface of the sample, and quantity of light admitted*. By the use of the ray filter, much more satisfactory results have been obtained, and it is thought that in this way less expensive objectives may be used with very good results. All photographs are taken at about 80 diameters for convenience in comparison of the structure.

*Offered as written contribution to the Discussion by Mr. W. J. Beck.

MR. HALL—I would like to say for the information of the members, that I have examined some brasses, and simply took a piece of sheet brass about ½"x1", and turned over the ends, leaving the face on top possibly ½" square. This is very simple and easily done, and furnished quite enough surface to show the structure.

MR. SCOTT—In the process Mr. Beck describes, is this preparation long and tedious?

MR. SKINNER—The process which Mr. Beck described required a comparatively short time. Simply bending a plate over, as Mr. Hall describes, amounts to the same thing so far as the shape is concerned. In our experiments we deal almost exclusively with steels never above .15 carbon, and in sheets of a thickness not exceeding 1-32" in any case. You will see, therefore, that we are working on a special problem which has very narrow limits as to chemical analysis. Professor Sauveur has spoken of the use of metallography in solving our specially difficult problems, and this particular work, which I mention, was instituted for the purpose of trying to solve one which we have not been able to solve, by this or any other method. It is probably known to a considerable number of those present, that steel used in electrical work has the property of "ageing". This was discovered about ten years ago, and electrical engineers have been endeavoring ever since to discover a way to cure it. This "ageing" consists in an increase in the electrical losses in the steel after it has been put in service. These losses are brought down to a minimum by properly annealing before the apparatus is built, and it was thought when this phenomenon was first discovered that it was due to the alternations of the magnetism to which this metal is subjected. It was soon discovered, however, that it was simply a phenomenon of heat, and that a temperature of 100 C. would, in some cases, age a steel 100% in ten days. Those of you who are used to thinking of steel as a permanent material may be very much surprised at this statement. We have found that many steels age

almost none at all, and that some age very much with no apparent essential difference in the chemical composition or physical construction. We have, therefore, resorted to the microscope, and considerable work has been done in that line. Like many others, however, we have been somewhat disappointed in that, we have not found what makes this difference. We have, however, found out a number of things which have been of considerable benefit to the work, and our efforts have, therefore, not been fruitless. In our examinations we have followed the material from the billet to the sheet, through all kinds of annealing, and I have some slides which might possibly be shown later, showing samples not annealed, and samples annealed as much as 25 to 30 times. I had hoped to get these on the screen and have Professor Sauveur make some comments, and I still hope we may have this later.

PROF. SAUVEUR—I would like to ask whether you have been able to find any relation between the ageing and the structure of the steel?

MR. SKINNER—No, we have not been able to ascertain any characteristics which seems to be peculiar to steel which has aged. We think we have a clue, however, and that in most cases we can distinguish material which will prove of good quality. This quality, by the way, varies considerably in steels of the same kind as well as in steels of different kinds. As to the cause of the phenomenon of ageing, pure and simple, we have, I am sorry to say, very little clue. In the first place, I may say that it is exceedingly difficult to test a particular piece for ageing and then make microphotographs before and afterwards. A sample for the ageing tests requires about 10 lbs. of the metal, while a sample for microscopic examination requires only a few grains, and it is very difficult to combine the results of the two tests or compare them in such a way as to be able to say this sample did change and this did not. The structure in a single sheet will vary in different parts, due to annealing, etc., and even in low carbon steel we found a very considerable difference.

Prof. Sauveur—It seems to me the best way to handle a question of that kind would be to mark a certain area on your piece of steel, take a photograph of it, then in due time ascertained whether that steel has aged, and by taking another photograph of the same area see if you can find any corresponding change in structure.

Mr. Skinner—I might say that the difficulty there, is the one I hinted at a moment ago, viz., to make measurements showing ageing requires about 10 lbs. of the metal, and we would have to take an average of several thousand photographs to be sure what part of the steel aged.

Mr. Scott—It strikes me there is a good deal of similarity between steel and bread. Different makers of steel may take the same materials and make widely varying mixtures; and we all know that cooks can produce both good and bad combinations from the same simple ingredients.

Mr. Skinner—Mr. Lewis has suggested that I explain that the ageing which occurs in steel is in a considerable mass of these thin plates built up, and we do not know whether it is one or the other or all which have to do with the ageing.

Mr. Tyler—I have been very much interested in the talk this evening, but I have had no practical experience in this line of work. I had hoped, however, for still better results than those we have so far secured. I also hope that we may be able to obtain satisfactory results from a determination of alloys in connection with the brass foundry, but at the present time we have not done very much in this respect. I remember of having an experience a number of years ago with a tool steel in which the trouble was finally found to be due to the tempering process and to lack of drawing the temper after plunging bath.

Mr. Hall—I cannot contribute anything more that would be of particular interest, but would say that we have examined some Babbitt metals which had exactly the same chemical composition, and they looked totally unlike each other

under the microscope. One showed a mass of very hard grains with crystals of copper and tin in the shape of six pointed stars. The other showed a large number of white or light colored crystals in comparatively small grain masses. While we have not as yet gone into the subject very deeply, this variation is undoubtly due to the heat treatment of the two Babbitts and possibly one was poured into some form of shell which affected its structure. I simply mention this as corroborating Professor Sauveur's statement of the effect of heating and cooling metals.

MR. SCOTT—I believe we are indebted to the Scientific Materials Company for the apparatus which we have here this evening. Mr. Davis of that company is present and may have something to say.

MR. DAVIS—I had not thought of saying anything in this connection, but I will say that if any one is interested in this apparatus, we shall be very glad to have them come to our store rooms at No. 711 Penn Avenue, and we will be glad to explain the apparatus, its manipulation, etc. As Professor Sauveur knows, the use of this apparatus along the line of metallography is somewhat new, and while being in the line of work developed largely under this direction we feel that we have much to learn as much as anybody else; but we purpose to carry a full line of material and endeavor to meet all requirements in this direction. We are, of course, interested in it from the commercial side and I will do all I can to look after matters satisfactoily in this connection. From the remarks made here by a number of our friends there is apparently going to be considerable interest in this line of work around Pittsburg. We feel that we can take care of the commercial side of the science.

MR. SWENSSON—I think the members of the Society would be interested in knowing something about the actual temperatures of annealing.

PROF. SAUVEUR—It is pretty well known that in order to

properly anneal a piece of steel, and in order to confer a fine structure upon it, the metal should be heated past the critical point, with which most of you are familiar, that is, the steel is heated to a certain temperature—generally in the neighborhood of 750 C. where it passes the critical point. You may start out with a very coarse structure, and when the metal passes through its critical stage or point, at about 750 C., that structure is destroyed entirely irrespective of its original condition.

(At this point Mr. Albree submitted two samples of steel forgings, which his firm is furnishing for the Government, one of which had been annealed, and the other not annealed; both being fractured to show appearance of the grain, and asked Professor Sauveur's opinion of the two structures. The Professor stated that judging from the appearance to the naked eye, the piece which had been annealed looked the coarser, and suggested that it might have been annealed at too high a temperature; he also remarked that the appearance of the fracture does not always indicate just what the metal is, however.)

Mr. Bole—Supposing that the temperature of annealing has been determined: Does the time in bringing that steel up to that temperature have any important effect; or the time that it is maintained at that temperature; or the time occupied in losing that temperature?

Prof. Sauveur—I think the important point is to heat the whole piece *through* and *through* to the desired temperature, and if you are dealing with pieces of large cross section, it would take a certain time to obtain that temperature. After you have once reached the proper temperature, however, I do not think anything is gained by keeping it at that temperature. However, I think the slow cooling is desirable.

Mr. Bole—Would not slow cooling have the effect of making the structure very coarse? Would it not make the steel rather poor looking?

Prof. Sauveur—The rate of cooling from a high temperature has a marked effect upon the coarseness of the struc-

ture. But, if the piece is only heated to the critical point, and cooled down very slowly, the structure does not change, because it is below the critical point. It is above the critical point that the crystaline changes take place. If the metal is heated only to the critical point, or possibly a little above, and cooled, the structure remains the same. But, if you heat it to a very high temperature, the rate of cooling would undoubtedly have a marked influence on the structure.

MR. BOLE—Mr. Bole, suppose a piece of steel was heated, and cooled very quickly by plunging in oil.

PROF. SAUVEUR—That would harden the steel. While the carbon is passing back into the cement condition, it is desirable to give all the time necessary for this process to take place. If you quench it too quickly, you would undoubtedly retain some of the carbon in the hardening conditions.

MR. LYNCH—I would like to ask if the quality of castings, and particularly large ones, could not be improved very much by covering same with sand, and allowing them to cool very gradually. Take a large casting, of say, 50,000 lbs., and it is a very difficult matter to cool it properly, and in the particular case I have in mind, I made a special request to have the casting covered as much as three feet with sand, allowing it to cool entirely before removing. Is not this a very good thing to do with heavy castings?

PROF. SAUVEUR—If you examined the structure of your casting, you would probably find it of a relatively coarse nature, and therefore, not as ductile as it might be made. By cooling in the method you described, you would undoubtedly relieve the cooling strains very much, and I am not at all surprised that it resulted in an increase of ductility.

MR. SCOTT—I would like to make a suggestion, Professor, which I am sure will be acceptable to many, if not all of the members, and that is that you give us the names of any books on this subject which may be published. We may want to look up some of these things.

PROF. SAUVEUR—I suppose you have all heard of "The Metallographist". (Laughter). A good text-book is very much needed, and it is to be hoped that one will soon be published. F. Osmond, a French Engineer has written a very good paper, which can be used by most students. I do not know of anything in English which would really give us the information desired. The French book I mention is published by the Societé d' Encouragement Pour l' Industrie Nationale of Paris.

MR. SKINNER—I might say that I have a translation of that French paper, made by a member of the Carnegie Steel Company, and it is very complete. I would also state that there has recently been a book published in English upon this general subject by Hiorns, which gives some very good information. I found it in Weldin's book store, in Pittsburg. The French translation to which I referred, consists of about 50 or 60 typewritten pages. (This translation will be found in these proceedings, following the discussion.)

MR. HALL—I am not acting in the capacity of a sales agent for the Professor, but would suggest that we get what he has published in that line. The publications are in four volumes, and it is a very complete treatise on the subject. These volumes also contain articles by all the well-known metallographists in this country and abroad.

MR. SCOTT—This is called the age of steel, and the steel problem is one of the most intricate and difficult with which we have to deal. We tried first to solve it completely by chemical means. We made chemical analyses, which, of course, assist us very materially. But, now we have a new instrument brought into the field, which adds still more to our sources of information. Who can tell but that there is some other realm beyond which will reveal other ways of getting at and solving this problem.

MR. YARDLEY—While listening to the talk here this evening, I have recalled with a great deal of interest, not only what

I know of this subject, but what I do not know. It puts me in mind of a conversation with Mr. B. F. Jones, whom you all know. I asked Mr. Jones some questions about the manufacture of iron. I thought then it was a simple question, and I have always remembered his reply. He said, "If you had asked me that question 20 years ago I could have told you all about it; now I do not know."

MR. SCOTT—I think the point Mr. Yardley brings out is a very good one, that is, to find out what we do not know positively. A gentleman came to me not long ago and said he wanted to find out how to figure on electrical apparatus. He wanted to know all about generators, how to get the right size, the best type, etc., etc. I told him that if he would pick out about one-half dozen of the young men who are at the heads of their several lines of work, and that if he was about to learn in the next month all they had learned in the last ten years, he might get what he wanted.

MR. S. B. ELY—I think the Society is very much indebted to Professor Sauveur for his very interesting and instructive lecture here this evening, and I move that we tender him a vote of thanks.

Motion carried.

MR. HIRSCH—The Programme Committee wishes to acknowledge the courtesies extended to the Society by the following companies for the loan of apparatus and instruments used on the occasion of Prof. Sauveur's lecture.

The Scientific Materials Co., Mr. C. H. Davis, Vice President, 711 Penn Avenue, Pittsburg, Pa. to whom the Society is endebted for use of the full complement of instruments used in the demonstrations during the lecture; The Westinghouse Electric and Manufacturing Co.; The Westinghouse Machine Co., also to Mr. F. C. Schatz of the House Committee, and his assistants, Mr. Harry Tieman and Mr. Wm. Blevins, for valuable aid rendered in setting up the apparatus to produce the direct current required.

MR. SCOTT—A committee was appointed at the last meeting for the purpose of nominating officers for the coming year. Is that committee ready to report?

MR. BOLE—The committee recommends the following ticket.

President, Chester B. Albree,
Vice President, James M. Camp,
Sec. Vice Pres., Samuel Diescher,
Director, Selwyn M. Taylor,
Director, Prof. S. M. Kintner,
Secretary, Mr. C. W. Ridinger,
Treasurer, Mr. A. E. Frost.

MR. SCOTT—These nominations will come before the annual meeting for election.

I would like to take this opportunity of welcoming the gentlemen here who are not members, and saying that I think you will find the Society a great help in your work, so that I hope you will decide to join us. We believe we have a Society here that is amply worthy of your consideration, and we feel that the more members of the right kind the stronger the organization will be. We have some little books here which you are welcome to take if you like. These very clearly indicate the nature and scope of our Society.

It has been a very pleasant custom of the Society to meet at the University Club on our Society evenings and informally dine there together. We have averaged something like fifty members there an evening, and it gives us the opportunity to have a very social time. Our Social Committee have thought to change the plan somewhat this evening (and I was going to say have saved the best part of the program until the last, but I cannot do this under the circumstances). The Committee, however, assures us of a good time coming in our own rooms here. At the University Club each man pays for himself 85 cents for dinner. Here there is no regular charge, for members; non-members are expected to help themselves but not

ferent reactions, and the recognition under all circumstances of the different constituents of steel. The system that I am about to describe, is not perfect, and certainly needs improvements to render it more sure. However, handled with prudence, it appears to me to be an instrument of some utility in the study of metallurgical problems. I dare not say for the solution of these problems, while definite solutions recede constantly before the searcher, and while each step in advance opens to us new regions, of which we know nothing, and also those which we think we understand.

For the clearness of illustration, I beg my readers to forget for the moment that which they have learned, and to remember only that steels, no matter what they are thought to be, are not homogeneous.

I do not mean to say that there is not much to cherish in the experience, which has been bequeathed to us by former works, but, it is always easier to build a house of new material than to repair and enlarge one. In proceeding thus I hope to render the initiation easier to the novice and engineers of works, who have neither the time nor the means to begin at the beginning.

As to contemporary workers, they will easily recognize, amid the material that I have put in the work, that which is of value, and adds to the general science.

PRELIMINARY OPERATIONS.

Leaving aside the study of fractures, to which, unfortunately, we can only apply low magnification, the first operation, when we wish to examine a specimen, is to obtain a plain surface. I take it for granted that the surface is obtained in the work shop by file, lathe, grind-stone or some similar method, chosen according to the hardness of the metal, and the conveniences at hand. It remains to polish the surface.

POLISHING IN GENERAL.

A professional polisher, should you go to him, first puts the test piece on a fine emery wheel, then on a buffing wheel,

covered with rouge and wet with water, and turning about 2000 times a minute. The result is satisfactory for tempered steel, but not for annealed. If you risk an observation, the workman will respond that it cannot be done better, and that the defects are in the metal, hence, we are forced to do it ourselves. But the list of professions, in which polishing plays a part, is of but little help.

For useful information, we must consult metallographists: Dr. Sorby and Prof. Martens were the first to lay down good technical rules for polishing metallic surfaces. Yet we perceive very quickly that, even following these rules as closely as possible, we do not arrive at the desired results at the first trial, or even after many trials. Each one must go through his apprenticeship, which the experience of others may shorten, but not supplant. This is said to guard my readers against premature discouragement. I will describe the method of polishing which I arrived at finally.

PREPARATORY POLISHING.

The process after all, is the same as that of the artisan in principal. Roughing with emery and finishing with rouge, but it is the details that are important. Lacking a mechanical polisher, I replace, in imitation of Dr. Sorby, the emery wheel of the work-shop by finer and finer emery paper placed on plate glass. These papers should be of regular grain. The powder should be sufficiently adherent as not to come off by rubbing, and the wear is done by scratches and not by gouges with incrustations, as happens when the powder is loose. Finally the paper and glue should not scratch the specimen of themselves.

The papers of commerce rarely fulfill these conditions, but, as we only pay one cent per sheet, we have no right to complain. It is better to make the papers which you need. For that purpose I buy emery powder, called 120 minute, i. e., that which has taken 120 minutes to settle in a vessel, of which I do not know the dimensions. I carefully spread this

powder in water, and collect the deposits at definite times in vessels. Here is an example of the amount deposited at the end of different periods of time:

SEPARATION OF 100 PARTS.

Deposited in less than one minute.........	16
" from one to two minutes....	13
" " two to five "	8
" " five to ten "	6
" " ten to twenty "	14
" " twenty to forty "	8
" " forty to sixty "	11
Not deposited in sixty minutes............	24
	100

We see that the commercial product is not uniform. The separated powders, when collected after being dried, are spread in a glue of the albumen which is employed in making photo paper, and spread on the best quality of paper. The papers thus made are not beautiful and show the marks of handling, but last a long time and are very good.

Without speaking here of the preliminary polishing, which should efface the coarser scratches, and for which the papers of commerce are suited. I am in the habit of rubbing my specimen 100 to 200 times on each 1 to 2, 2 to 5, 5 to 10, 10 to 20, 20 to 40. It is good to cross the scratches at each change of paper, to see whether the scratches of the preceding paper have left any scratches deeper than others. The finest papers are not used. The other colored powders, which most likely contain more hydrated peroxide than emery, encrusts the soft metal and depolishes rather than polishes.

When the emery paper is good the polishing may be finished directly with rouge, or without any intermediate powder. Neither is the commercial rouge of suitable quality. The rouge known as "Steel Rouge" is too hard, and too coarse for steels not tempered. The rouge for gold is generally better; even then it must generally be washed.

I believe that these materials alter with time; maybe by a molecular change, and in an oxide of iron this is not unlikely. In brief, it is better to prepare your own rouge carefully, avoiding the presence of all hard impurities, calcine the copperas at a definite temperature and separate by washing the finest parts of the produce, the only part that can be used.

Bert Henrivaux, the well-known Director of the Plate Glass Works at St. Gabin, wished to save me the trouble and gave me a sample of his oxalate rouge, which is very good and which has been very useful to me. I powder with this rouge a piece of smooth cloth stretched in double thickness on a cast iron plate on a little horizontal polishing machine. The machine in question came from Germany, where I saw it in the laboratory of Prof. Martens at Charlottenberg. It is constructed by Luess at Steiglitz near Berlin, and cost 60 marks. You hold the test in your left hand, pressing it against the cloth, wet with distilled water, and turn the crank with your right hand at the rate of 200 turns per minute.

When the polishing with emery paper has been well done, the scratches rapidly disappear. One has more difficulty to get rid of the small holes found most often in soft steel, which seem to come from gouging, and which it is important to get rid of, in order not to confound them with porosity. Soft steels should be polished twice as long as hard steels. It is best during the last part of polishing to press as lightly on the cloth as possible.

We finally obtain, or should obtain, a nearly specular surface, even when the metal is not homogeneous, providing that the cloth is not too wet or the rouge too coarse. But this surface usually shows only the presence of slags, fissures or porosity. Ordinary polishing is not in itself a very useful means of investigation, but only a preparation for some other process of micrographical analysis.

We now commence the description of the special processes, which is the object of the present work.

GENERAL METHOD.

This method comprises three successive operations. 1st, relief polishing; 2nd, etch polishing; 3rd, etching with chemical reagents.

1st. *Relief Polishing.* When we polish a substance which is not homogenous, its different constituents tend to wear away unequally, following their specific properties and absolute dimensions, and, under favorable conditions, showing the structure by the unequal relief of its elements. This is relief polishing. Dr. Sorby, Dr. Martens, and especially M. Behrens, obtained by this method, may-be by design or perhaps accidentally, interesting specimens.

The method is not new. I only strive to make the use of it more systematic, and the manipulation easier. To obtain the desired results, we must polish on a surface that is elastic enough to grasp the small inequalities in proportion as they appear, and delicate enough to show up or cut out the finest details. That which I find the best is parchment, which Dr. Sorby has already made use of.

We stretch it out, wet, on a level wooden block, and tack it down. To use it we must wet it again and powder with rouge, as we did previously for the cloth, but we must this time guard against having rouge in excess. We first spread on the parchment, and rub in well the small quantity applied. The block is then put under a water faucet and washed, brushing it in such a way as to leave no rouge, except the finest particles, which are held in the pores of parchment. On this we rub the metallic surface, adding from time to time a few drops of water when it is necessary. The hard constituents appear in relief in proportion to their relative resistence and greater dimensions.

Two thousand rubs going and coming for 8 cm. is generally enough. Nevertheless the finest rouge is still too coarse, and it may be necessary to continue the polishing, always on wet parchment, with precipitated sulphate of lime. I have

also employed, sometimes with great success, but more often with inexplicable failure, barium sulphate.

We can thus resolve certain details, but the work is long and difficult, and, fortunately, it is not often necessary.

The test being prepared, it remains to distinguish under the microscope, a relief from a depression. We determine this, provided the test is not colored, by the aid of an artifice, which, no doubt is not unknown, though I have not seen it described anywhere. It is necessary to close the aperture of Beck's Vertical Illuminator by a small diaphragm 2 to 5 m. in diameter. We place the objective a little below the point of focus, and raise it gradually. The parts which appear first relatively bright and yellowish, on a relatively dark back-ground, are in relief.

The depression presents an inverse appearance so well that photographs of the same test, taken a little above and a little below the middle point, are nearly negatives of one another. The distinction is particularly clear with objective No. 5 of Nachet & Son. That is to say, for an enlargement of 200 to 300 diameters. It is less clear for higher magnification, with No. 9 immersion of same make, but we are guided by the shadows, especially near the edge of the field.

2nd. *Etch Polishing.* The second operation consists of adding to the mechanical action of the polishing powder, which is chemically inert, that of a reagent which is inert by itself, but in which the activeness is produced by rubbing. We thus obtain singular effects.

Ammonical water not only does not oxidize steel, but preserves it from oxidation; hence, I was very much surprised one day while polishing a piece of soft steel with dilute ammonia and barium sulphate, to see my steel shade gradually and successively into all the colors of temper in their habitual order, and in such a way that the hard constituent always was one degree in advance of the soft part. Never has direct heating of the same metal furnished so good an illustration. I have not, however, deduced any results from this.

The reagent I use for etch polishing, not less known than ammonia, is an infusion of licorice root. I found on employing it with rouge and sulphate of lime, containing the base relief polishing, it colored certain constituents before, or to the exclusion of others. There remains to be learned what is the active substance or property which the licorice root gives to the water. While waiting a solution of this problem, I am in the habit of macerating 10 grms. of licorice root for hours in the cold, in 100 c. c. of H_2O and filtering. This infusion spoils very quickly, and becomes more and more active, and ends by attacking the metal. It should not be kept more than eight days, and it is preferable to use it of the same age and concentration.

3rd. *Etching.* After etch polishing, we put the test back on the polishing machine to remove the relief and the color. We then etch it in the ordinary sense of the word. The reagents that can be used may be divided into three classes: acids, the valogens and salts.

The final result of dissolving steel in the principal acids is relatively well-known. But, the initial process of a very incomplete action in a dilute solution, is more obscure and probably more complex. Hydrochloric acid of 10.5, or 2 parts to the 100 of water, (the test may or may not be connected to the positive pole of a Grenst cell), sulphuric acid 10 parts to the 100, chromic acid (the reagent of Abel), hydrochloric acid in absolute alchol, (the regaent of Martens) have all been used, but none of them seem to me to be better than nitric acid, which is more generally used, and which will be described later.

We may use, according to circumstances, 36 deg. Baumi acid, or dilute it with water to 20 parts to the 100, or 2 parts to the 100.

The valogens, which attack iron, and separate the carbon entirely, have a more simple action than the acids. I am very well satisfied with tincture of iodine. This tincture should not be prepared with absolute alcohol, as it will give a very slight

and very irregular etch, from which nothing can be learned. That sold by druggists is suitable.

I apply it in successive drops; one drop to the square centimeter of surface. It is allowed to work until discolored. After the test has been examined, the operation is, if necessary, repeated. The first application is generally sufficient, and sometimes even too strong.

Sulphate of copper, bi-chloride of mercury, chloride of gold and potassium-platino chloride are salts, which replace the dissolved iron by a deposit of their metal, but have never given me very encouraging results. The number of my experiments, however, was very limited, and I may have missed the favorable conditions, and I would not dissuade anyone from repeating the experiments.

In the end I only used tincture of iodine, and occasionally nitric acid. Wash the test after etching in tincture of iodine in alcohol. After etching in nitric acid, wash with alcohol and water, and dry with a fine cloth. Drying in an air jet is preferable, when it can be obtained.

The drying is omitted when an immersion objective is to be used. With the aid of these three successive operations, relief polishing, etch polishing and etching, and by means of the reactions, which they show, we will try and define the primary constituents of steel.

THE PRIMARY CONSTITUENTS OF STEEL.

I call primary constituents, all parts of the structure whose micrographical reactions would show to be elements. These constituents, without counting slag, are five in number. But the list is very provisional, as in the case of ordinary substances, and for the same reasons. The progress of the science may bring discoveries, which may increase or decrease the number.

1st. The first constituent of steel is iron—pure, or practically pure, as absolute purity is mythical. When we consider iron as an element of structure in a complex aggregate, it be-

comes necessary to give it a particular name, and I have given it that of "Ferrite", invented by M. Howe, in imitation of mineralogical terms. Ferrite, under relief polishing, at first keeps a specular surface, but if the operation is prolonged, and, moreover, if we finish the polishing with sulphate of lime and water, it granulates more quickly and deeply when it is less dense. When in masses of some size, it resolves at length into polyhedral grains. Polishing on parchment with sulphate of lime, and an infusion of licorice root produces the same effects more rapidly, and produces no coloration.

Tincture of iodine shows the same results in three or four applications, under conditions already described. Ferrite never colors, providing it is sufficiently pure and dense. Nitric acid also shows the joints of the grains very well, but it colors, or does not color, according to circumstances so complex that it is necessary to examine.

If we place under the microscope, illuminated with the vertical illuminator, a test of extra soft steel in nitric acid, of 2 parts to the 100 (2 volt. of acid 36 deg. Baume in 998 vols. of water), and watch the etching for half an hour, we see certain grains turn yellow and brown progressively, while others tarnish without coloring or remain nearly intact. The grains that have turned brown generally remain so after drying. On making the same experiment with acid of 2 parts to the 100, the ferrite takes beautiful colors, differing from one grain to another, and often in the same grain.

These colors are the same as produced in the air by tempering, and we have at the same time yellow, brown, purple, blue, green, or uncolored grains, with continual transformation. The design acquired on emerging is more or less injured by drying. It is difficult to follow the rapid etching produced by acid 20 parts to the 100, but an acid of that concentration often furnishes, after drying, a specimen in which the ferrite is more or less eaten away, but not colored. These facts lead us to believe that the attack begins with the formation of a

thin film of oxide or some other substance, which later dissolves in the bath.

According to the formation of the design, at a certain point progresses more rapidly or more slowly than its dissolution, the colors appear, or do not appear, and, when they do appear, may, under favorable circumstances, run through the color scale, either ascending or descending. The phenomena are so complex that they cannot, even in the cases most studied, be exactly predicted. We can never tell certainly when we etch a steel with nitric acid on a given concentration, and during a given time, whether we will obtain the ferrite, and, moreover, all the ferrite colored, or not colored. Nitric acid, although it can render excellent service with known steels, for example to determine the final temperature of hot working, is a dangerous reagent for micrographical analysis, and has led me into errors more than once, as I have not yet learned its manner of acting. At any rate, its indications should be controlled by other means, and no doubt the same may be said of all the other acids.

2nd. The second constituent of steels is carbide of iron, which was forseen by Karsten and Caron, and isolated more or less intact by F. E. G. Muller, Sir Fr. Abel and others.

It is a carbide to which results that were the same, although obtained by different methods, have given the probable formula Fe_3C. The iron in steels containing manganese, or chrome, may be replaced in different proportions by this manganese or chrome. I give Fe_3C as the probable formula, because no one has ever succeeded in isolating it pure and intact.

Mr. Howe calls it "Cementite", and carbon which is found in definite composition has been called "Carbon of Cementation" (carbon), the carbon of annealing (Osmond and Worth), and the "Carbon of the Normal Carbide", (Ledebur).

It is in cement steel that cementite is found in the largest masses, and is most easily studied. It will form at the same

time large straight lamellae running parallel to each other, similar groups bound in a large polygonal network, and simple lamellae, often curved and inter-stratified with ferrite. But, notwithstanding the doubts of Dr. Sorby, doubts which I shared for a long time, I think that to-day we can identify the "Cementite" of cement steel with the hard constituent of cast and forged steel. My opinion was confirmed by the analysis of M. Ledebur, who showed through the identity of the composition, and also by my last micrographical observations. It is true that M. M. Arnold and Reed have distinguished, in the residue left by treating steel by Wely's method, two carbides of different aspect, one brilliant and white, the other being dull and gray. The difference seems to reduce to this: that the brilliant lamellae are compact and smooth, while the dull lamellae are rough and poorly united.

The characteristic property of "Cementite" is its hardness. Dr. Muller likens it to that of feldspar.

The variable numbers 5 to 7, given by Prof. Behrens, are explained thus: The hardest kind being due to the presence of chrome, and the softest to the lack of density, which has already been mentioned. Cementite is the hardest constituent in steels (including steel that has been water-hardened and not re-heated) and hence is easily shown by brief polishing, providing that it is not spread through a soft mass in such a finely divided state that the microscope cannot distinguish it. Then it can only be determined by Chemical Analysis.

Etch polishing with sulphate of lime and licorice, as far as I have carried it, does not color cementite. Tincture of iodine applied eight times, always under the conditions indicated above, does not color cementite, and it appears silver white under perpendicular illumination.

It does not color for 40 seconds at least in cold nitric acid of 20 parts to the 100, and in acid of 2 parts to the 100 it does not color for a much longer time.

3rd. Passing to the third constituent of steels. Mr.

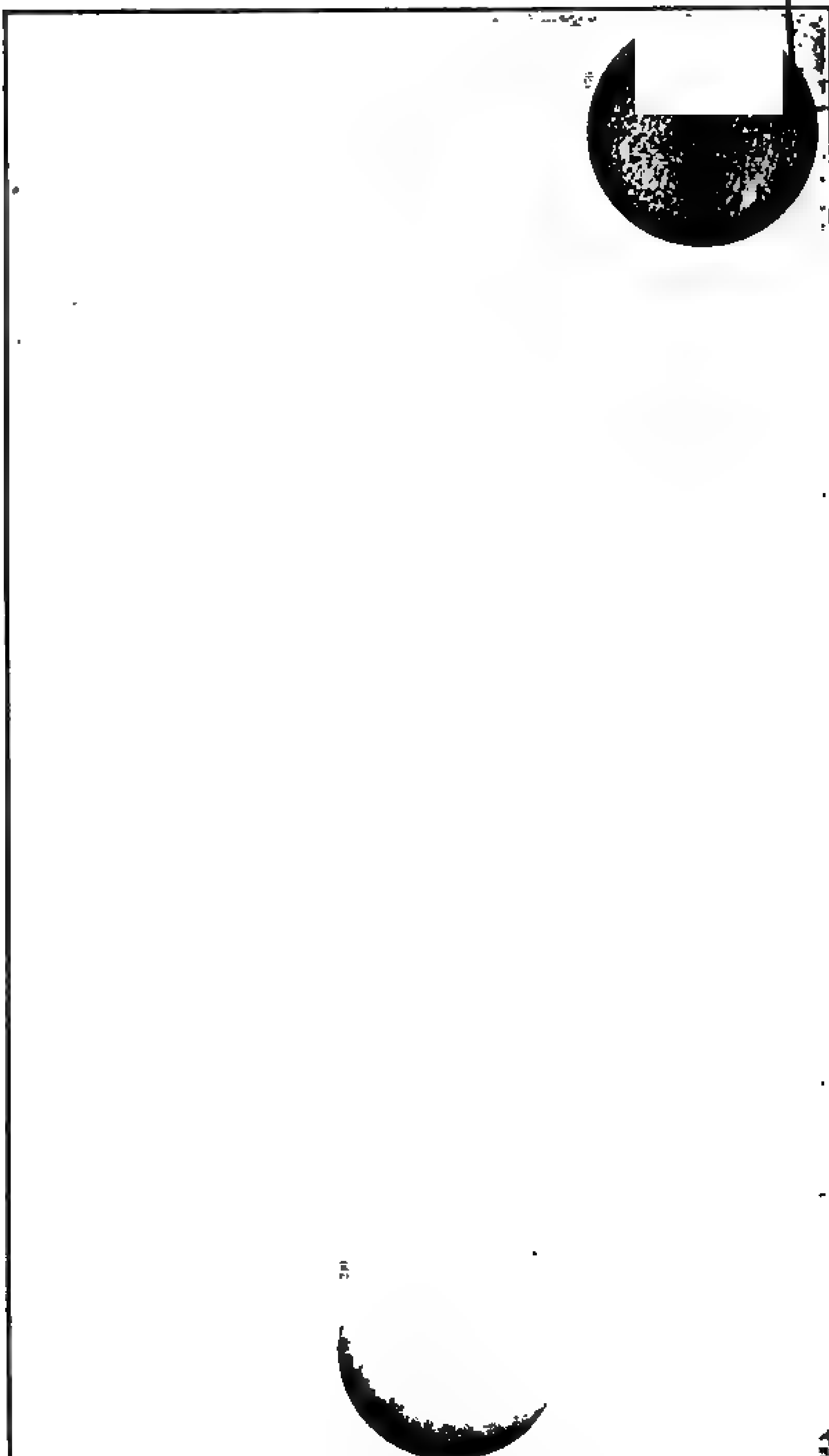


Plate 5.

Sorby described it first under the name of "the binary constituent", a very fine mixture of alternative hard and soft lamellae, which Mr. Howe calls pearlyte (Fig. No. 249, Plate 5 shows it at 800 magnification, an example obtained by etch polishing). This mixture, from which it has taken its name, shows under oblique illumination, because of its structure, the iridescent colors of the mother-of-pearl, provided the polishing or the etching has eaten away to a suitable depth the soft or solvent lamellae, but there is no need of laying any great stress on the optical phenomena, which are already understood and which have already been explained by Tresuel. As a direct chemical analysis shows in all steels, or especially in annealed steels, a greater or less proportion of carbide, Fe_3C, i. e., cementite.

It is generally admitted, without reserve, the hard lamellae of the pearlyte is cementite, the soft lamellae ferrite, and that the pearlyte is exclusively a mixture of the primary constituents already described.

But is it always thus? Take steel of 1.25 carbon, annealed at 750 deg. C., which is almost entirely formed of pearlyte conforming to the discription of Sorby. Polish it by 2,000 rubs on a parchment web with water and rouge and examine it under the microscope with perpendicular illumination. The alternate lamellae appear clearly at some points, as is shown in figure 249, Plate 5, but it is the exception. Nearly all over one sees clearly the lamellae structure, but, as already remarked by Dr. Sorby, very unequally developed, and with reliefs very often so indistinct that the photographic reproductions at an enlargement of 800 diameters completely lack clearness. This first fact leads us to suspect that the alternate lamellae are not always so different in hardness as ferrite and cementite. But the absolute thickness of the lamellae may also play a part, and the finest among them, which scarcely exceed .001 of a m.m. may not be resolved by the polishing.

Perhaps because the grains of rouge are relatively too

large, or maybe because the relief being too fragile, they break off gradually as they appear. This explanation certainly contains a portion of truth. But, continue the experiment by etch polishing. The spots poorly resolved by the rouge do not resolve much better, but instead, at the end of a certain number of rubs, some of it commences to color, following, as we proceed, the ascending scale of the temper colors, yellow, brown, purple, blue. At a given moment the colors are very different from one spot to another. On a given spot, characterized by a definite orient action of the lamellae, the design may be continued, always following the same stripes, or clearly discontinued.

The uncolored lamellae themselves may be in bas-relief, or high relief. We obtain results altogether analogous with iodine, on the application of the first drop of the tincture, even diluted with an even volume of 95% alcohol, and Fig. 344, Plate 5, shows such a test, with spots well or badly resolved.

But neither the ferrite or cementite color under the same conditions, with either the infusion of licorice root, or iodine. We are, therefore, decidedly in the presence of a new primary constituent, which I call "Sorbite", in honor of the first pioneer in metallography.

The facts herein contained, show that the alternate lamelae of the pearlyte can be formed sometimes of cementite and sorbite; sometimes by sorbite and ferrite; sometimes by two sorbites differently colored, and sometimes by cementite and ferrite, with or without the inter-position of sorbite. I believe but cannot say surely, that the ferrite and cementite are never in immediate contact, owing to the difficulty of telling whether the test is colored by the etching, or by the light. It is very likely, at any rate, after what we know of the proportions of the cementite in a steel, and what we see of the area occupied by this constituent on the prepared surface, that the cementite may be diffused into the sorbite in so finely divided state that an enlargement of 1,000 diameters will not resolve the mixture.

I have proved the existence of sorbite to my own satisfaction, but, I know nothing positively of its chemical composition, and, in default of a mechanical method of separation, the problem is not easily solved.

Now, if you reflect that the carbon in steels is never integrately in combination in the cementite, one is lead to believe that the carbon in sorbite partakes of the variety called hardening carbon; that, which volatilizes in the attack by the method of Mueller, and colors nitric acid relatively little. This is only a supposition, and awaits further developments.

4th. The fourth constituent of steel, is that obtained by water hardening. It is not new, but the structure is not yet known. Dr. Sorby speaks with the greatest reserve of an extremely fine grain. Prof. Behrens mentions in certain specimens, that he has examined the existence of a soft polygonal network, but, this network is the beginning of a superficial decarbonization.

The researches of Prof. Martens, apply to steel more or less soft, and show the unequal distribution of the carbon in the steel, but not the ultimate structure of the hard portion. I published in 1891 a photograph of medium hard tempered steel, which showed in oblique light, after being etched in nitric acid, a very clean watered appearance, but I interpreted this observation very badly. In short, as we see the grain diminish, on tempering steels containing much carbon, until it can no longer be seen with the naked eye, we would naturally believe that the structure of tempered steel tends to become amorphous. It is, however, as we shall see, distinctly crystalline.

Take, as a good example, 0.45 carbon steel heated to 825 deg., and tempered at 720 deg. in a freezing mixture of 20 deg. The structure only appears dimly on relief polishing, which shows that the hardness of the material is about uniform, but it appears well on etch polishing. (Fig. 260, Plate 4.)

We then see in slight depression, groups of needles, or

PLATE 4.

rather straight fibres in parallel formation, and sometimes separated by a rough or vericulated substance. Three systems of fibers, respectively parallel to the three sides of a triangle, often intercept in the same region and characterize, according to information given to me by M. Michel Levy, crystals of the cubic system. I call this constituent "Martensite", from Prof. Martens, who established in Germany, in 1878, an independent center for metallurgical research, and has since then continued his studies with much perseverence, skill and success.

Martensite, shown by etch polishing, is either not colored, or is a pale yellow after 2000 rubs on parchment, wet with licorice water. It is colored, on the contrary, by the first drops of tincture of iodine to a yellow brown, or black, according to the percentage of carbon; the fibre always appearing clearly. Because of this difference in coloring and etching, we cannot say positively that Martensite is a primary constituent of steel.

But the observed facts may also be explained by the juxtaposition of the first fibres, and the tendency of these fibres to eject the carbon from their organism. Being in this doubt, it is natural to adopt provisionally the most simply hypothesis.

Whatever it may be, martensite preserves its form as well in the parts of soft steel, that have been hardened by tempering, as in the hardest steel; with this sole difference, that the less the percentage of carbon, everything else being the same, the longer and more divided are the needles. It is because of this characteristic, that we are able to recognize it in steel of different hardness. It is, therefore, certainly not a definite liquated combination of iron with carbon; it represents the crystalline organization, under the influence of carbon, of one of the allotropic varieties of iron. The forms that we find preserved by rapid cooling may, however, be pseudo-amorphous, and I do not give them as a sufficient argument in favor of the actual presence of the corresponding allotropic variety in tempered steel.

5th. We have now only to examine the fifth constituent

of steel. It is in the medium hard steels, tempered during the transformation of the iron, that it is most plainly seen. Let us take again a 0.45 carbon steel heated to 825 deg. and tempered at 690 deg. Relief polishing shows spots in relief, and strips that are depressed, and, between the two, a binding of variable size and intermediate hardness. After etch polishing, we ascertain that the hard spots are martensite, and the soft strips ferrite. As to the interspersed binding, it is colored with the temper colors, but less rapidly than either ferrite or sorbite, under the same conditions, and the coloring is irregular like that in marble (Fig. 208, Plate 5).

The structure is nearly amorphous, very slightly granular, and uneven. The first or second application of tincture of iodine, gives the same effect. The fifth constituent, which is more nearly related to me, I will call "Troostite", after a friend who has rendered great service to the science of metallurgy.

We see that troostite is a transition formed between the soft iron and quenched steel. But, like Sorbite, it is only recognized by its micrographical reactions, and its chemical composition has yet to be determined.

MICROGRAPHICAL SEPARATION OF THE CONSTITUENTS.

As we know the five constituents of steel, and the way each behaves under the different operations, we can take up the analysis in its application to the Micrographical Separation of the Constituents. The following are abstracts made from the operations of polishing.

1st. Polish in relief on wet parchment covered with rouge (2,000 rubs) and examine under the microscope. By continuing the polishing with sulphate of lime and water, the joints and grains of the Ferrite may be made to appear, but this may be more easily shown with iodine or nitric acid.

2nd. Polish on parchment with sulphate of lime wet with licorice water. Examine with the microscope after every 500 rubs. It is not generally necessary to exceed 2,000 rubs, but we must take into consideration the age and concentration

of the licorice water. A certain amount of personal experience is indispensable. The presence or absence of color divides the constituents into two groups; Martensite, however, is sometimes colored and sometimes uncolored:—

(A) Constituents which do not color { Ferrite, Cementite, Martensite.

(B) Constituents which color——— { Martensite, Troastite, Sorbite.

Martensite, which at most only takes a yellow color, is recognized by its crystalline form. An experienced observer might confound it with Pearlyte, especially in an oblique light, because it may give rise to the same color phenomena, and the elements of the structure may be of the same size. The distinction, however, is not hard. The principal needles of the Martensite are straight and often intersect. The lamellae of the Pearlyte are generally curved and never intersect.

Ferrite and Cementite may be distinguished by their difference in hardness, which shows the first depressed and the second in relief with respect to all other constituents. In the second group Troastite colors more gradually and less uniformly than Sorbite, but the real difference is that Troastite is the companion of Martensite, while Sorbite is that of Cementite in Pearlyte.

3rd. After replacing the last on the polishing wheel to remove the color and relief, we etch with iodine; one drop to the square Cm. and let it act until discolored. Wash with alcohol after each application. Dry and examine under the microscope. The first application should be made with a tincture of one-half the ordinary strength. It is rarely necessary to make more than two or three applications.

Iodine again divides the constituents into two groups:—

(A) Constituents which do not color { Ferrite, Cementite.

(B) Constituents which color——— { Sorbite, Troastite, Martensite.

The three constituents of group B are classified in the order in which they show color. The tone and intensity of the coloration varies with the percentage of Carbon, and the quantity of the reagent employed. In the first group we can, if we wish to make a chemical distinction between Ferrite and Cementite, try to color or tarnish the Ferrite by putting the specimen in nitric acid two parts to the 100, and letting it remain from ten to twenty seconds, but the results is always uncertain and is seldom used, except for hard steels. It would be very useful if we could find a more certain reagent.

This seems to be, while awaiting new developments, the best method to obtain satisfactory results. I do not wish to convey the idea that the method given equals in accuracy and precision that of petrography, or chemical analysis. In the first place the different constituents are not definitely etched, or not etched by the different reagents, they are more or less etched, or are not etched during a given time.

Again, no constituent has a definite composition. Pure Ferrite does not exist, and we are obliged to consider it approximately pure iron. Cementite, it is true, has a formula, but it may spread itself out and separate in the Sorbite. Sorbite, Troastite and Martensite appear to be solidified solutions of different forms of Carbon in different forms of iron, and pass gradually into Ferrite when their percentage of Carbon diminishes. The Sorbite of annealed steel and the Troastite of quenched steel appear to unite for certain rates of cooling, which are neither very slow nor very rapid.

These rates may be obtained in practice by quenching in oil or lead. We have, therefore, often to deal with transition forms, which are the despair of the Classifier. But the Classifications are none the less necessary, and the divisions which I have made will enable me, I hope, to show more clearly how

the structure of steel varies with the variation of the percentage of Carbon, and how it changes under the influence of heat and according to the rate of cooling.

DETAILED EXAMINATION OF A FEW STEELS.

My experiments were with four specimens of steel, with increasing percentages of Carbon, the other impurities being present in small quantities and varying little. The first of these specimens has exceptionally little Carbon. The second represents soft steel used for sheet iron. The third is medium hard steel, for common rails, armor plate, etc. The fourth is tool steel. This is the chemical composition.

	1st.	2nd.	3rd.	4th.
Carbon	.02	.14	.45	1.24
Silicon	.05	.04	.07	.35
Sulphur	.02	.01	.01	.01
Phosphorus	.03	.01	.03	.01
Manganese	.25	.19	.35	trace

The transformation of the structure is confined to the critical points, hence it is necessary to determine these points. The results are shown by the curve in Fig. 1, page 22, constructed by the same process I employed in my previous publications, that is to say that the abscissae are the temperatures and ordinates are the times it takes the thermometer, under the given conditions of cooling, to descend one degree to the thermo-electric pyrometer of M. Le Cahtelier (about 10° C.)

The essential figures are collected in the following table, attached hereto. During the heating, the 1.24 Carbon steel shows a stationary temperature, for a time at 705 deg. C. The 0.45 Carbon steel also shows this, but not to such a marked degree.

I recall that the point Ar 1 corresponds to Barrettes point of recalesence, and the transformation of the Carbon from the hardening Carbon to the Carbon of annealed steel, while the points Ar 3 and Ar 2 show the allotropic changes in iron.

The results of experiments made in 1891, and mentioned

for the first time in 1892, in a report "On the Method of Cooling," made before the Commissioner of Testing Methods, experiments that have since been confirmed by M. Curie, show that these two changes in iron are distinct, something that my previous researches did not determine. In other words, the steel is in the V. state, above Ar 3; B, between Ar 3 and Ar 2, and L. below Ar 2.

The work of Dr. Ball and M. Curie, made very probable the existence of a 4th allotropic state, above 1300 deg. C. or, maybe, a return to the B state.

All my specimens were originally forged. The first in squares of 6x6 mm.; the three others were round, and 12x13 mm. in diameter; from these last two discs, 7 mm. thick were cut from the cold metal.

The forging of these last was finished at a dark red heat, in such a manner as to give the finest possible grain, but without crushing. It was my idea in thus starting with forged metal to destroy all lack of homogenity existing in the raw casting. The structure of ingots, and the changes made in them by working, tempering or annealing, should be studied by themselves, and have already been made the subject of an important memoir, presented by M. Martens, at the Chicago Congress.

The specimens having been prepared as described, were subjected, under exactly fixed conditions, to different heat treatments; hardened or annealed, determined from the position of the cricital points, and which will be shown at the same time as the Micrographical Analysis.

As it is important to define doubtful terms, I shall call "Annealed" all heats above Avl, followed by a cooling which is slow enough not to disturb the points of transformation, no matter how long the maximum temperature was maintained. I call "Quenched" all coolings which are rapid enough to displace the transformation points, and I call "Revenu" all reheating after quenching up to a temperature lower than Arl, whatever may be the subsequent cooling.

In all my annealing experiments the specimens were held between two plugs of asbestos, placed in the tube, heated in the furnace of Leclercq and Farquignon, and reached the desired temperature in 30 minutes. The tubes were then closed and left to cool, the furnace being covered.

With tests that have undergone a heat treatment, it is necessary to remove with a file or grind-stone about 1 mm. of the surface, in order to remove any metal that may have been superficially oxidized or carbonized. Only transverse sections are of importance in microscopic analysis. Longitudinal sections are also of interest, but only for the study, deformations taking place when the piece is hot; a study which is not the principal object of this article.

After this general description, we will go on to detailed examinations of the four steels selected.

Steel containing .02 Carbon. This metal is a product of smelting, and originally contains .07 Carbon. M. Hadfield, who kindly furnished me with it, lowered it to .02 by a prolonged annealing in oxide of iron (the process for the manufacture of malleable castings). The rest of the analysis given in the table was made on the metal before annealing in M. Hadfield's laboratory. During the annealing, the oxidizable elements, such as Silicon and Manganese, were probably partly scorified. The percentage of Carbon after annealing cannot be stated absolutely, but at any rate relief polishing does not show any Cementite.

Annealing and hardening at different temperatures, including white heat, does not produce any appreciable change in the structure, and the description of one of these structures will do for all. The preliminary polishing showed numerous inclusions of slag. The network of joints in the Ferrite begins to develop under the relief polishing and etch polishing, but the same structure may be shown much better and more easily by etching with the tincture of iodine (3 applications of a drop each, left undisturbed until the drop discolors.)

The black patches (Fig. 307, Plate 2, 100 diameters) are slag. The Ferrite is in large grains, very irregular in size and shape, which may be sub-divided into grains smaller, more regular and less clearly shown. The grains are attacked very unequally, and in view of the pureness of steel, this is no doubt due to a difference in density between the grains, or even in the same grain.

It seems, from the result of the examination of this specimen, that the structure of pure iron is independent, at least within certain limits of the temperature of heating and the rate of cooling

Steel containing .14 Carbon. (Forged Metal.) After polishing in base relief (Fig. 96, Plate 2, 100 Diameters) numerous scattered filaments, more or less distorted, are shown in relief, and appear dark in the photograph taken a little above the middle point. These are strips of Pearlyte, a mixture of Cementite and Sorbite, which may reduce to a simple lamellae.

Prof. Wedding has already shown this by heating in the temper colors, and described it under the name of "crystalline iron." The remainder is Ferrite. By a prolonged polishing on parchment with sulphate of lime and water (11,000 rubs for the sample under consideration) we gradually show a net work separating the Ferrite into contiguous polyhedric grains, and joining the strips of Pearlyte, which are almost always external (Fig. 100, Plate 2, 100 Diameters.) The grains themselves do not form a specular surface, some being slightly depressed, and others slightly in relief, as is shown by their relative amount of illumination with the different positions of the objective.

This is more plainly seen by the variations, in the shadows, under a higher magnification (Fig. 101, Plate 2, 400 Diameters.)

After etching with four applications of tincture of iodine (Fig. 322, Plate 2, 100 Diameters) some grains are slightly colored to a yellow or brown, which seems to show the presence of traces of Carbon. The Pearlite is shown by dark spots.

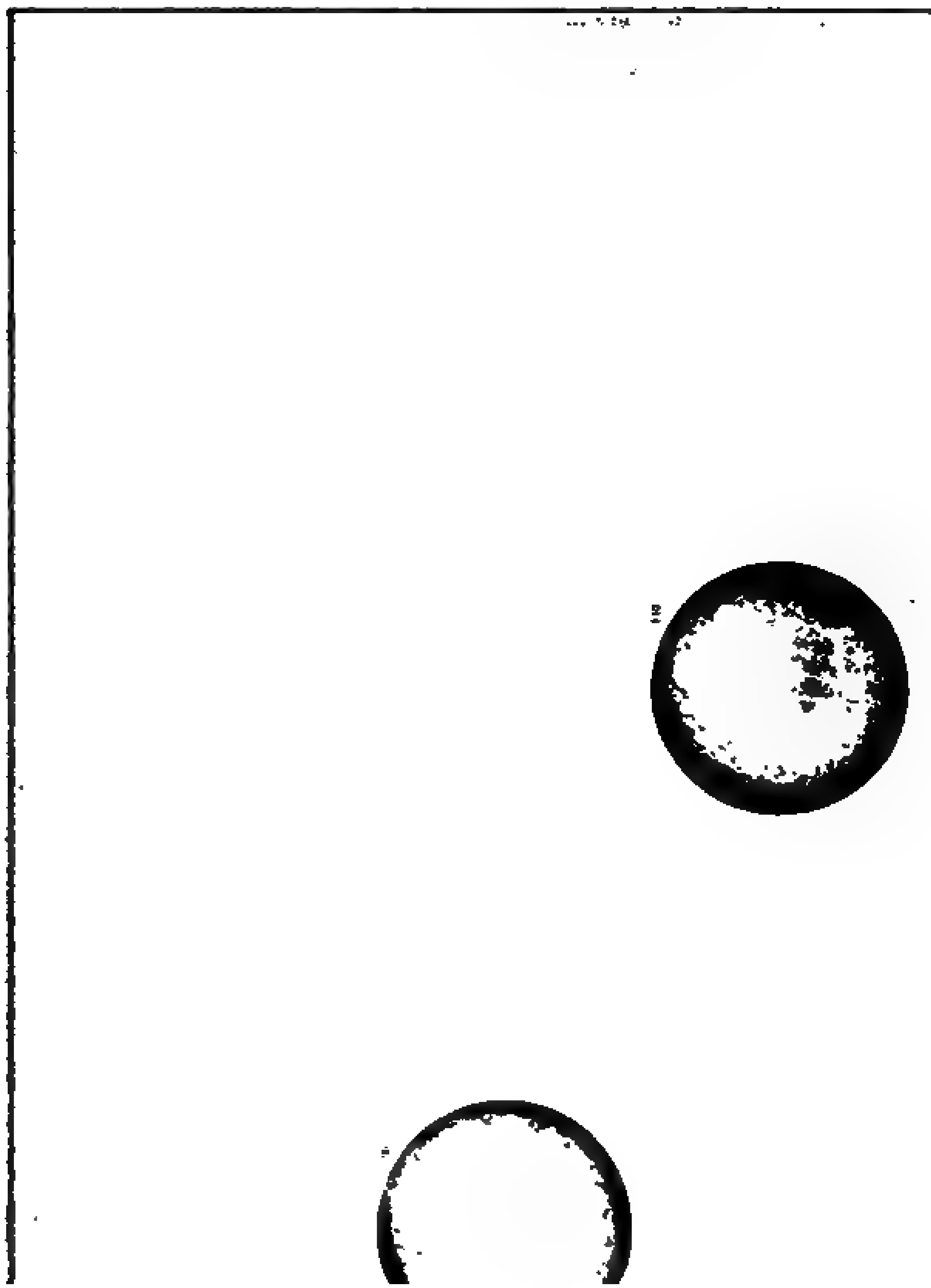


PLATE 2.

After etching with Nitric Acid, 20 to the 100, for 12 seconds, some of the grains are deeply etched, while others are not attacked (Fig. 162, Plate 2, 500 Diameters.) The Pearlyte of the enlarged joints is not clearly shown. On selecting a spot on the test, and following each grain through the different phases of the operations, both by photograph and superimposing diagrams, I did not find any definite relation existing between the reliefs due to polishing, the colors produced by iodine, and the etching of Nitric Acid.

The observed facts may be attributed to several causes, principally to the unequal distribution of the foreign matter, and the difference in density. This question of density or porousity is as important in microscopical micrography as it is vexatious. I do not mean the porousity that may be seen with the naked eye or the microscope, and which is common in cast steel, and which is found in the central parts of pieces forged or laminated, but I mean that invisible porousity which can be no larger than the molecules themselves, and which shows the effects of polishing and etching.

It is this that largely explains the different colors taken by the different grains of the same constituents, when subjected to the action of acids in general, and especially very dilute Nitric Acid (50 Vols. or more of water.) It is because of this that I restrict, and do not advise the use of these reagents in the work.

The body of the Ferrite may be considered as an agglomeration of globules, more or less stuck together, which seem to show, when suitably etched, a tendency to arrange themselves in the form of pearl mica or lamellea. The net work of these joints separates the grains into polyhedral, which may be pentagonal dodecahedra more or less distorted.

We see that the method of analysis used enables us to make, in the structure a very soft steel, a distinction between joints and strips of Pearlyte which etching, especially deep etching with Nitric Acid, tends to hide. This distinction once

made, Nitric Acid (20 to the 100) is very useful in making a rapid determination of the average size of the grains in specimens roughly polished.

(*B*) *Influence of Annealing.* As the temperature rises, other things being the same, the polyhedra of Ferrite enlarges slowly at first and keeping their shape. Above 1,000 degrees, they become irregular, and tend to elongate into groups of juxta posed bonds. The Pearlyte generally remain outside the formation of the Ferrite, and stratifies to the joints.

For a given steel, the form and dimension of the grain is characteristic of the annealing temperature, with enough precision for all practical purposes. The three figures, 157, 159 and 160, Plate 2, show, at the ordinary magnification of 100 Diameters, and after etching with Nitric Acid (20 parts to the 100) the same forged steel. Annealed or not annealed at 750 deg. (157.) Annealed at 1015 deg. (159) and annealed at 1330 deg. (160.)

(*C*) *The Influence of Quenching.* The first specimen was heated at 960 deg., at which temperature the point Acs is certainly passed, and cooled slowly to 670 deg. and quenched, that is between Ar 1 and Ar 2, in water at 15 deg. Relief polishing shows many inclusions, thicker, less spread out, and less distorted than those in the annealed specimen (Fig. 140, Plate 2, 100 Diameters.)

The rest of the analysis shows that these inclusions are no longer Pearlyte, as in annealed steel; they are not scratched by a needle. This is Martensite, with a fine binding of Troostite, which blackens on etch polishing. Iodine or Nitric Acid show that the remainder is Ferrite in polyhedric grains, exactly the same as those in steel cooled slowly from the same temperature.

A second specimen was heated like the first, to 960 deg. and quenched at 770 deg., that is between the points Ar2 and Ar3. The hard grains are put in relief, by relief polishing, and which are resolved, and colored yellow by etch polishing

(Fig. 142, Plate 2, 100 Diameters) are much larger than in the previous specimen, but their hardness is scarcely greater than fluor spar, as the Carbon is more diffused. Looking at it at a magnification of 500 Diameters (Fig. 145, Plate 2) or better, after etching with Iodine, at a magnification of 800 Diameters (Fig. 313, Plate 2) we see that it is formed of parallel needles, which the licoric water has cut out, and which the Iodine shows light on a dark ground. Two groups of needles often cut in the same region. These are the characteristics of Martensite. We find on the outside strips of Troostite. As to the principal soft body, it is as before, grains of Ferrite. The same specimen etched with strong Nitric Acid is scarcely distinguishable from annealed steel.

A third specimen was also heated at 960 deg. and quenched at 820 deg., that is, during the transformation Ae3. Its structure is intermediate between the one preceeding and the one following, and needs no special description.

The fourth specimen was heated to and quenched at 1,000 deg., that is before Ar3, in water at 15 deg. The Ferrite has again contracted, and now occupies only half the surface. The structure appears after relief polishing, as a depressed cellular network (Fig. 143, Plate 3, 100 Diameters) in which the nuclei are colored by Iodine or Nitric Acid (Fig. 163, Plate 3, 100 Diameters.) The relief of these nuclei is very slight, as their mineralogical hardness is not much greater than iron. Examined at a magnification of 500 Diameters, after etch polishing (Fig. 173, Plate 2) it shows the Ferrite resolved into elongated grains, to which are bound the soft needles of the Martensite.

A fifth specimen was heated and quenched at 1340 Degrees, a little above the point Ball mentions. The structure appears very well of relief polishing. The Ferrite proper binding about polygons of large size (Fig. 166, Plate 3, 100 Dia.) The interior of these polygons is seen to be Martensite by its remarkably developed crystalline form, (Fig. 167, Plate

PLATE 3.

2, 100 Dia.) but it is Martensite verging on Ferrite, because of its small percentage of Carbon.

Seen in oblique light it is sometimes dark and sometimes light according as the inclined surface of the parallel needles reflect the incident rays on or outside of the objective (Fig. 168, Plate 3, 100 Dia.) This is so plain that on turning the specimen under the microscope we can see a polygon light up and go out at every turn like a flash light. Etched in nitric acid (20 parts to the 100) it shows clearly in the same region the orientation of the elements following the three sides of a triangle and the crystalline forms of the cubic system.

To complete this set of experiments, I compared with the steel above described as heated to 960 Deg. and quenched at 770 Deg., another specimen heated to 770 Deg. and quenched immediately. I found no marked difference.

III. 45 Carbon Steel.

(A) Forged.

Similar steel have several times been described by Dr. Sorby, Feeding, Martens and others. They are formed of a vermiculated mixture of Ferrite and Pearlyte. Etch polishing gives the best results. (Fig. 175, Plate 3, 100 Dia.)

The Pearlyte conforms to the general description that has been already given. Etching resolves the Ferrite into grains that are not always very homegeneous. Some of them, especially those that have been elongated by forging, have a central nucleus slightly in relief and colored (See Fig. 2, Page 28) and which seems changing to Sorbite. This nucleus may reduce to a simple joining line, with or without a filling of Cementite.

(B) Influence of Annealing. I will pass rapidly over this subject, as it has already been discussed. As the temperature increases the Pearlyte forms more and more regular polyhedra, about which the Ferrite makes a more and more perfect network, thrusting into the interior of the crystals parallel branches.

Figure 179, Plate 3, 100 Diameters, shows a steel annealed at 1015 Deg. after etch polishing. The same specimen at a magnification of 800 Dia. (Fig. 184, Plate 2) is a good example of Pearlyte well resolved. Etching with nitric acid (20 to 100) leaves the Ferrite white and blackens the Pearlyte, (Fig. 186, Plate 3, 100 Dia.) This etching is too strong, if we wish to study the fine details of the Pearlyte, but for a steel already known, it furnishes sufficient information and, as it does not require perfect polishing, it is often used in manufactories.

After annealing at 1390, the metal is burned. The Polyhedra have become so large that a photograph at the low magnification of 20 Dia. is necessary to give an idea of the general effect (Fig. 192, Plate 3.) In this the illumination is oblique, and, hence, the ordinary apparatus is reversed, that is, that the Ferrite is black and the Pearlyte bright. Fig. 190, Plate 3, shows the same specimen at a magnification of 100 Dia. and at the vertex of three polygons. The binding of Ferrite and its branches may easily be seen. These bindings are divided by an axial line which may not appear clearly in the photograph. These are joints of contract and sometimes open into cracks where the introduction of oxidizing gases may, at that high temperature, from a layer of slag. This accounts for the brittleness of burnt steel. The Pearlyte is not easily resolved by etch polishing, and the Cementite is very much spread out in the Sorbite.

I should like, in passing, to call the attention to a new form Pearlyte, i. e. vermiculated. It is, however, local (Fig. 329, Plate 3, 800 Dia.) iodine etch. These examples appear to be exclusive. There is no metal that shows the temperature of annealing so plainly as steel of average hardness.

(C) The influence of quenching. (A) Heating to different temperatures and quenching at the same in water at 15 Deg. This series of experiments permits us to follow the diffusion of Carbon during heating.

The first specimen was heated and quenched at 730 Deg. Relief polishing shows a large disconnected network of Ferrite. Etch polishing shows about this Ferrite a border, more or less wide, of Troostite, which is colored brown with blue spots (Fig. 294, Plate 3, 100 Dia.) The rest is Martensite. This is more rare in certain places and the Troostite much more abundant (Fig. 253, Plate 3, 100 Dia.) At a magnification of 800 Dia. the needles of Martensite are easily seen. The bright grains are Ferrite with its dark binding of Troostite (Fig. 255, Plate 3).

Etching with nitric acid, 20 to the 100, (Fig. 257, Plate 3, 800 Dia.) gives the same indications, but does not resolve the details of the Martensite. We see that about 20 Deg. above the point of recalescence the Carbon is not yet spread through the entire mass of steel. At 1,000 Deg. the diffusion of the Carbon is practically complete. Steel quenched at that temperature takes almost throughout a specular suıface when relief polished (Fig. 216, Plate 4, 100 Dia.) but the test is cracked through along one diameter. It is all Martensite, except at a few points, where, in the vicinity of inclusions of slag, thin fragments of Troostite exist, sometimes surrounding traces of Ferrite.

The needles are longer and more regularly grouped than in the specimen quenched at 730 Deg. The limits of the crystalline group, which are usually quite indistinct, are lines of least density, which, when etched deeply with nitric acid, show black, and may transform into veritable fissures. The fissures, whether microscopical or not, may follow the direction of the needles. Hence, there exists in quenched steel a veritable net work of surfaces of weakness. This network may be the result of the combination of surfaces ot maximum tension during rapid cooling, with the surfaces of minimum resistance, created by the actual structure. This network may be shown by placing a polished surface under a layer of water some millimeters thick and pouring on it successively three drops of concentrated nitric acid.

This is the method of M. Worth, and prevents the hardening Carbons redissolving. The polyhedral elements seem to approach pentagonal dodecahedra, like the grains of soft annealed steel. These grains are rudimentary when the quenching temperature is just correct, but as this temperature rises, the grains become larger and larger, and more and more cut away. It is these that appear in fractures.

A third specimen was heated and quenched at 1225 deg. The diffusion of the Carbon is naturally as complete as in the specmen quenched at 1000 deg., and with greater cause. The martensite is, therefore, the only constituent, but the crystals are very clear and well developed. The needles are easily resolved by etch polishing (Fig. 224, Plate 3, 800 Dia.) or by nitric acid, 20 to the 100 (Fig. 226, Plate 4, 800 Dia.) We also obtain beautiful watered effects in oblique light with low magnification (Fig. 225, Plate 4, 20 Dia.)

This effect is useful in studying the cause of the formation of the grain above described. We can find all the different surfaces of weakness. 1st, the crack visible to the naked eye, which is always broken (Fig. 220, Plate 4, 20 Dia.,) (etch polished.) 2nd, the line of least resistance at the common vortex of two crystalline developements (Fig. 226, Plate 4 already mentioned.) 3rd, the line of least density, or greatest tension, which in traversing a crystalling region, follows a different direction from that of the natural cleavage, and is shown by a deeper etch of a certain size among the separate needles. (Fig. 336, Plate 3, 800 Dia.) iodine etch. (Fig. 339, Plate 4, 100 Dia.) iodine etch permits us to follow, under an oblique light, the progress of a fissure generally, but not always, coinciding with the limits of the crystalline sport, having the same orientation.

A fourth specimen was heated, and quenched at 1325 degrees. It does not differ from the one preceding, except by a new crystallization, and does not require a special description.

(6) Heating to a constant temperature, followed by quenching at different temperatures in water at 15 deg.

The constant temperature of heating 625 deg. was selected, in order to obtain the complete diffusion of Carbon, and include the other transformations at the same time, avoiding the formation of a network of surfaces of weakness. This series of experiments will enable us to follow the concentration of the Carbon during cooling, as we have already followed its diffusion during heating, and to show that this concentration is entirely made in the zone of the critical points.

The first specimen was quenched at 720 deg., that is, before the beginning of the double point Ar3; 2nd, (See curve on page 22), and after slow cooling from 825 deg. to 720 deg. relief polishing, followed by etch polishing, show almost all martensite, and only in some places, where the Carbon was scarcer, a residue of the ferrite together with troostite, and isolated filaments of the last named constituent.

Figure 212, plate 4, 250 dia., was taken from one of these spots. A second specimen was quenched at 690 deg., near the maximum of Ar3, 2. The ferrite has increased, and relief polishing shows numerous strips which, however, are not yet jointed (Fig. 207, Plate 4, 100 Dia.)

Licorice water, iodine and nitric acid produce almost the same structures as we found in the same steel heated and quenched at 730 deg., see Figs. 208, (Plate 5, 100 Dia.), (etch polished); 332, (Plate 4, 800 Dia., iodine etch) and 206, (Plate 4, 800 Dia., nitric acid etch), and compare with Figs. 253, 254, 255, 257, (Plate 3.)

A third specimen was quenched at 670 deg. between the maximum of Ar3.2, and the beginning of Ar1. The general structure is the same, but, the before mentioned isolated strips are jointed, and now form a thick continuous, cellular network, easily eaten away by relief polishing, (Fig. 202, Plate 4, 100 Dia.)

A fourth specimen was quenched at 650 deg., during the middle of its recalescence Ar1. The ferrite now appears as it did in the forged metal, and its appearance after relief polish-

ing is also the same, (Fig. 197, Plate 4, 100 Dia.) Compare with Fig. 175, plate 3. But, if we etch with nitric acid, 20 to the 100, for about two seconds, certain grains turn black and others only yellow, (Fig. 199, Plate 4, 100 Dia.) The first are martensite, that is quenched steel; the second are pearlyte, or steel that has not been quenched. The grains of martensite are first attacked in the center, where the organization is clearer. Fig. 325, plate 4, which is in detail, and at a magnification of 800 dia., shows grouped in a circle $\frac{1}{1000}$ m. in dia., the five constituents of steel. The point of recalescence being passed at about 640 deg., quenching no longer produces any visible effect, but looks like the structure of forged steel.

(C) Heating to a constant temperature (825 Deg.) following by quenching at a constant temperature (720 Deg.) in different mediums.

The baths chosen were:

1 Deg. A freezing mixture of 20 deg.
2 " Water at 15 deg.
3 " Water at 85 deg., which gives the same effect as cold oil.
4 " Melted lead.

We saw above, that after a preliminary heating to 825 deg. to ensure the diffusion of Carbon, and quenching at 720 deg., that the quenched metal is almost entirely formed of martensite. It is the same, and with greater cause, when quenched in a freezing mixture. But quenching that is not too sudden allows the formation of a network of ferrite, very much the same as if the quenching was done in cold water, but at a lower temperature. Fig. 229, plate 4, shows at a magnification of 800 dia., and after an etching that leaves the ferrite white, the steel quenched in hot water. Etch polishing, Fig. 337, plate 4, 800 dia., shows in the middle of the polygons various colors looking like marble, but which are not shown in the photograph.

The needles of martensite have about disappeared, and the

lammelae of pearlyte have not had time to separate. We have here transition forms between troostite and sorbite.

(D) The influence of "revenue" (tempering.)

If we reheat to a brown on one side and a blue on the other, a specimen that has previously been heated to 825 deg. and quenched at 720 deg. in cold water, prolonged relief polishing again shows some martensite, but only at the edges of the field, and so slightly that a photograph shows nothing distinctly (Fig. 240, Plate 5, 800 Dia.)

Etching with nitric acid shows better in some places the characteristic triangles (Fig. 242, Plate 5, 800 Dia.) But the martensite structure here is but the image of a previous structure, and no longer corresponds with the actual state of association of iron with carbon. Chemical analysis shows that cementite is again formed, but it is in so fine a state of division that it cannot be seen with the microscope. A drop of iodine colors it variously, the colors often being mixed in the most complete disorder. Here are found all the forms of transition between the constituents of steel (Fig. 340, Plate 5, 800 Dia.)

On reheating to 670 deg. we get a little order in this chaos. The cementite and ferrite tend to separate, and the ferrite to collect into badly defined grains, on the outside of which the cementite is diffused in the sorbite. But the liquation remains very incomplete (Fig. 238, Plate 5, 800 Dia.)

Another specimen was heated to 890 deg. after being quenched at a white heat, and etch polished. We see side by side (Fig. 245, Plate 5, 800 Dia.) a sort of fish bone, very characteristic of the structure due to quenching, grains of ferrite encircled, but without any sharp line of demarcation, with a network of sorbite, and in one place, in the path of the transformation, we see where the new organization has taken place in the yet visible frame-work of the old.

IV. 1.24 Carbon Steel. (Forged Metal.)

(A) There may be found near the axis of the specimen a hard portion, which is found in most specimens.

This hard region is a good example of pearlyte, and is shown in Fig. 249, Plate 5, 800 Dia., and has already been described. Fig. 208, Plate 5, 800 Dia. shows another spot in the same location. Etch polishing gives no appreciable coloration, which means that the sorbite, supposing that it occurs, is reduced to so thin a layer in contact with the cementite that it cannot be seen. In the remainder of the test the cementite is collected, probably by forging, which terminated below Anl, into spheroids of variable size. Fig. 345, Plate 5, 800 Dia. shows it remaining bright after the sorbite has been colored with iodine, and the ferrite with nitric acid, 2 to the 100.

(B) The influence of annealing. In the specimens annealed at 750 Deg. the relatively thick filaments of cementite thrown in relief by relief polishing, seem, at a low magnification, to form a sort of cellular network. But, under a higher magnification, they resolve into rough isolated strips.

The body of the test is pearlyte, which is more or less resolved by etch polishing, and of which a detailed description has been given before in connection with the sorbite (Fig. 344, Plate 5, 800 Dia.)

At 1015 deg. the hard nucleus is burnt, and divided into beautiful polyhedra by a continuous cellular network of cementite. At 1330 deg. it is entirely burnt; the polyhedra are of large size and frequently separated by fissures with a fine binding of ferrite, which is most likely caused by the introduction of oxidizing gases. As for the remainder, the principal part is always pearlyte, whatever may be the temperature of annealing; only the higher the temperature, the more the groups of parallel lamellae tend to develope.

The best method to determine the annealing temperature or the finishing temperature of steel of this hardness, is to etch with concentrated nitric acid, 36 deg. baume. The etching is limited by the passivity. It is apt to be too deep if we wish to study the details of the pearlyte. But, for the same reason, it furnished in an oblique light, and at a low magnifi-

cation of 50 deg., a watered appearance, which is more developed as the temperature is raised. It will suffice to compare the two extremes. Figures 11 and 9 (Plate 5) show the effect of annealing this steel at 750 deg. and 1350 deg. respectively.

(C) The influence of quenching. The study of the quenching is very simple, the cementite is so finely divided in the ferrite, and the carbon has not far to go in diffusing. The three critical points reduce to one, and we pass much more rapidly from pure martensite to pure pearlyte. A specimen was heated and quenched at 735 deg. in water at 15 deg. Quenching at this temperature already produces cracks. Three fissures visible to the naked eye start from a common point at about the center and go toward the edge, but do not reach it. These fissures are broken like those of fig. 220, plate 4, and often split, separating out small regular polyhedra.

Relief polishing shows in relief strips that are harder than the quenched steel and remain bright after etching for five seconds with nitric acid 20 to the 100, and surrounded with a very black ring. This is the residue of cementite which corresponds to the thick strips of the same constituent found in steel annealed at the same temperature (Fig. 284, Plate 5, 100 Dia.) Thus at 30 deg. above the point Arl, the reciprocal point of the recalescence, the carbide is not entirely decomposed, or, if it is, it's carbon has not yet been diffused. This is an interesting fact, and one that will be mentioned in the conclusions.

As for martensite, it has it's characteristic forms and shows them in the usual manner. But the needles are smaller and less distinct than we have previously seen, especially in the hard nucleus. Although we can easily see them under the microscope, at least when we are accustomed to examine the smallest details, I have not succeeded in making a good photograph.

This difficulty does not exist when the quenching is done at a white heat. Etching with concentrated nitric acid, under

FIG. 3. C-1214

Position of Critical Points during Cooling.									
	Ar3			Ar2			Ar1		
	Beginning	Max.	Ending	Beginning	Max.	Ending	Beginning	Max.	Ending
Steel of .02 C.		855°		760°	740°-720°	700°		Missing	
" " .14 C	840°	825°-815°	808°	750°	730°	700°	655°	650°-640°	655°
" " .45 C				715°	695°	Uncertain		650°	630°
" 1.24 C							700°	675°	650°

C-1215

a layer of water, several millimeters thick, shows rather large triangles (Fig. 293, Plate 5, 800 Dia.) in which the lines shown clearly are colored with the different colors of temper. It is to be remarked that the difference in color does not correspond to any appreciable difference in hardness, because relief polishing leaves a specular surface, and even etch polishing shows nothing after 2,500 rubs. The body of the test is, however, divided by a multitude of cracks, large or small, into polyhedra so poorly united that some of them are broken out by the preliminary polishing on emery (Fig. 290, Plate 5, 20 Dia.)

Quenching during recalescence in water at 15 deg. gives a mixture of martensite and granular pearlyte, with or without the interposition of troostite. Figure 305, plate 5, 800 dia. shows an etch made with nitric acid, which leaves uncolored the martensite and small grains of cementite in a matrix of sorbite and ferrite.

If we assume, as would appear legitimate, that rapid cooling fixes, in a general way, the structure acquired at the moment of immersion, the results shown by micrographical examination of specimens quenched at different temperatures may be summed up as follows:

Let C1, C2, C3, C4, C5 be the areas, shown diagrammatically by the small black circles (Fig. 3a, Page 36 of original paper) which are occupied in the section of an annealed steel by the constituents cementite and sorbite. Suppose for simplicity, that the circles C1, C2, C3, etc., have their respective centers placed in the center, and four corners of a square. Also suppose that the absolute amount of Carbon in each is the same. We will now gradually increase the temperature.

At the point Ac1, the cementite, Fe_3C, is decomposed, and spreads its Carbon in the form known as hardening Carbon. Whatever may be the chemical signification of this term, the thing acts nearly as if the Carbon was a gas expanding under constant pressure. Up to the end of the change Ac1, the situation may be represented by the diagram 3C. The black

circles representing cementite, C1, C2, C3, reduce to the smaller circles, C'2, C'2, C'3. About these, the cross hatches circles represent the areas where the distribution of the hardening Carbon is uniform (martensite.) These last are themselves encircled by a dotted ring, which represents a zone of transition (troostite.) The remainder of the surface which is left white is practically pure iron (ferrite.)

At a slightly higher temperature (Fig. 30) the cementite has disappeared. The cross-hatched circles (martensite) have enlarged to a new diameter, a function of the temperature, and always preceded by their ring of transition. The pure iron is reduced.

If the temperature continues to increase, the cross-hatched circles do also, and the rings of transition join (Fig. 3d.) Then the areas of martensite join (Fig. 3e) and finally cover the entire surface (Fig. 3f.)

This progressive diffusion of Carbon takes place in a variable range of temperature, the range being smaller for hard steels, as the carbide portions are nearer together. It may remain incomplete in very soft steel. Inverse phenomena take place during cooling. Hence, we can find in steel at a red heat, that is above Ac1 or Ar1, the five constituents we have found in cold steel.

They may, or may not, occur at the same time.

1 deg. Ferrite.
2 " Martensite.
3 " Cementite.
4 " Troostite, (a zone of transition between ferrite and martensite.)
5 " Sorbite, (a zone of transition between martensite and cementite.)

In each of these constituents, we shall try and follow the transformation of iron and the carbon, and the organization of the final structure. This is constituted under the influence of

two groups of forces. Crystalline forces and mechanical forces, (tensions and compressions due to contraction or expansion). These forces unite to create in steel surfaces of weakness.

Those surfaces that are caused by crystalline forces are called cleavages. To the others it is convenient to give the name joints, a name that has already been used.

The origion of these joints are similar in some ways to the fissures in the crust of the earth. But questions of this kind are more familiar to geologists than to metallurgists, and I do not pretend to apply to the study of steel the work of Elie de Beaumont, Robert Mallet, or M. Baubrie. I shall only point out some points of similarity.

1. Ferrite. In the absence of Carbon, the transformations in iron take place normally; one between 700 deg.—750 deg. and the other near 855 deg.—850 deg., and in both directions. They may be retarded in a measure if the rate of heating or cooling is increased, but it is doubtful if they may be even partially suppressed, no matter how rapid may be the fall of the temperature.

What kind of structure correspond to the different allotropie varieties of iron? This is something that the study of pure iron will not teach us, as the presence of foreign matter seems to be necessary, in order that these varieties may be retained at an ordinary temperature. In fact, we do not have particularly pure iron except in the A state.

Again it is hard to separate, in its actual organization, the forms that properly appertain to it from those which have been bequeathed to it by pseudo-amorphism, and previously passing through the B & Y states. As we have seen before, the A iron consists of a mass of small globules, more or less connected, which shows a tendency to arrange themselves in the form of pearl mica and in lamellae.

The mass is sub-divided into polyhedra, the form of union has been described. When the temperature was not too high,

these forms are nearly regular, and we can recognize, without trying hard, pentagonal dedecahedra. Are the polyhedra in question crystals or grains? Are their surfaces of contact cleavages or joints? The answer does not appear doubtful. The body may be crystalline, but the network is not.

We can obtain by synthesis exactly similar bodies of compressing plastic spheroids in a mould. The dessication of damp bodies, and the solidification of cast substances show evidence of similar divisions. Here again we have to deal with forms affected by contraction and expansion. We can however attribute them sometimes to shrinking, sometimes to the change in volumes that accompany molecular changes, and often to the mutual limitations, with or without the interposition of gas, of the crystalline developement in developing from beta iron to gamma iron.

An experience of M. Arnold, shows that the elongated polyhedra produced by forging at a dull red heat will resume their normal form at about 750 deg., which brings it to the beta state of iron. Together with this, we may also cite the fact that certain alloys of iron with silicon or aluminum alloys, that do not pass to the gamma state, keep their regular polyhedra after being heated at a white heat, while under the same conditions the polyhedra of soft steel change to lamellae, and near the fusion point, change to cubic crystals perfectly developed.

But these are conjectures, and the formation of the ferrite brings up many difficulties, especially because of the possible intervention of the impurities, which are always present.

II. Martensite—During the heating, at and above the point Acl, the carbonized regions of soft steel differ in no way, except size, from the entire mass of hard steel. This is the same when cooling down to Arl. We know, however, that in hard steel the three points, A1, A2, A3 are combined during heating as well a cooling. Hence it will be the same in the carbonized regions of soft steel. The transformation A2 and A3 when they are independent, do not apply, as I once believed,

to the entire mass; but only to the part that is iron, and the point A1 is always a triple point, but a triple point which is local, or general, according to the percentage of carbon.

During heating, wherever the hardening carbon is diffused and has acquired sufficient pressure, the iron changes suddenly from the alpha state to the beta state, and from the beta state to the gamma state; and as the areas of diffusion increase with the temperature, the transformations of the iron progress with the progression of the carbon. They reach their normal temperature only in the places where this substance has not previously penetrated. Inverse phenomena take place on cooling; the carbon begins to contract and concentrate near the original centres of expansion or near others.

By degrees the iron returns from the gamma state to the beta state, and from the beta state to the alpha state, and these two changes take place, or do not take place, according to the temperature at which the carbon withdraws. Finally when the point Ar1 is reached, a portion of the mass, varying with the percentage of carbon (it will be the entire mass in hard steels) will retain the gamma form. Now we know that rapid cooling retains part of the carbon in the state of hardening carbon.

Does the hardening carbon in turn retain at the ordinary temperature part of the iron in the beta or gamma state? It is thus that I explain hardening, by a theory that appears to me more and more probable in its principle, although it is little worked out in detail. It should, however, develop with the progress of our researches. In regard to this theory I cannot give any new and decisive evidence.

The micrographical analysis of quenched steel shows that the diffusion of the hardening carbon causes in iron crystalling arrangements of the cubic system, i. e. martensite. But the carbon seems to distribute unequally between the body of the crystals and their envelope, as if it follows by preference the interstices of the crystalline elements, but with a certain ten-

dency, opposed by an inverse tendency, to penetrate into these elements.

The mean mineralogical hardness, varying between the Nos. 3½ and 6 of Moh's scale, excludes, however, the presence of a definite liquated combination. The carbon appears to take the part of a mineralizing agent, which causes the mass to crystallize by an action not yet understood, about in the same manner that traces of hydrochloric acid will transform into specular iron an indefinite quantity of amorphous peroxide.

The observed crystalline forms belong only to the gamma iron, because the beta state is only transitory in the presence of Carbon. After a short period of confusion, at the moment of the molecular change, they rapidly organize and enlarge as one temperature increases. But, in this growth the individual groups are limited by polyhedra faces, and thus create a network of joints, loosen and more plainly marked in proportion as the temperature was high. These joints turn to cracks in burnt steel, and completely isolate the polyhedra grains.

But, before reaching this point it always causes in steel a network of surfaces of weakness, independent of the possible cleavages between parallel needles. During cooling, the shrinkage tends to form another network of weakness, and the changes in volume due to the transformations of iron and carbon may also act in the same direction. It is believed that these different networks are probably superimposed, the first that forms opening a way for the others.

It is true, if the cooling is rapid and the steel hard, that the strains caused by shrinking open fissures, preferably following the joints of the grains. If the cooling is slow, the structure acquired by the iron in the gamma state forms at the moment of recalescense the skeleton in which the organization of the new structure takes place.

The lamellae of the pearlyte seems to correspond to the needles of the martensite, being more deferred as the initial skeleton was less solidly constructed. But, neither is the net-

work of weakness following the limits of the crystalline groups destroyed. It may open from the strains caused by shrinking, or from the loads maintained in service.

Hence, it is necessary to prevent as much as possible the formation of this network, and, therefore, not to heat the steel above the point "C" by Tchernoff. The definition that I have give before of the point "C" (in another work) appears to be correct. It is the temperature which must not be passed when heating steel, in order that the crystalline organization, which is produced at that temperature, does not leave any easily visible traces in the fracture of the cold steel, and the accompanying deterioration in the mechanical properties.

In this way the point "C" may be considered practically as the beginning of crystallization, although the true beginning is much lower, and coincides with the appearance of the gamma iron. The double meaning, theoretical and industrial, of the term, "beginning of crystallization" together with the fact that many authors call "crystals" what I call "grains," and a distinction between the grains of ferrite and those of martensite appeared necessary, has been the cause of misunderstandings which I did not clear up without much trouble. These explanations may make this clear the others.

"Revenue" (tempering) followed or not followed by a rapid cooling, also leaves the network of joints, which may have been caused by heating at too high a temperature, hence, it of course leaves the fissures produced by quenching.

But on the contrary it does not reconstruct the similar network of joints that form of ferrite, during slow cooling, in the places that the carbon has left. Continued to the neighborhood of Ac1 (690 deg.) it allows the ferrite to separate out in grains, but as we have seen, these grains have no distinct limits, and gradually pass into sorbite, mixed with very finely divided cementite. It is partly this, that according to reports on annealed steel, gives the superiority to the same steels that have been submitted under suitable conditions to "revenue" (tempering) after quenching (for double quenching).

III. Cementite. We have observed in the study of hard steel that a residue of cementite may remain undecomposed at 30 deg. above the maximum of Ac. 3. 2. 1., which confirms, in the heating curve, the existence of a connecting link between this point and the adjacent portion.

The decomposition of the carbide Fe3C (which may be written FeA3C because this magnetic carbide contains iron in the A state) is not sudden, and takes place as if the decomposition was limited by the tension of the hardening Carbon, exactly the same as the liberated carbolic acid will, in a closed vessel, limit the dissociation of carbonate of lime.

The sorbite then represents the atmosphere of carbon necessary to the existence of cementite. Hence, we see that under a sufficient pressure, cementite may be held long after its point of decomposition is passed. This explains the indentity of white pig iron before and after quenching. But the above considerations do not apply to FeA3C itself, which ceases to be magnetic at a certain temperature, and which like iron, has its point A2, but to an allotropic form FeB3C or FeY3C. Here there is a problem for work that I will reserve.

IV. Troostite. The presence of troostite in certain quenched steels gives the impression of a zone, generally narrow, which separates during the critical intervals the non-carburized regions from those of regular carburization. All we can actually say from its topographical position and the circumstances that allow us to observe it, is that it corresponds to that period of transition when the transformations are taking place.

For this reason, troostite (or some other form) occupies a large portion of steels subjected to a gentle quenching.

V. Sorbite. This is also a zone of transition between cementite and ferrite in cold steel, between cementite and martensite in steel above the point A1.

The study of sorbite is related to the study of the transformations of cementite, which are themselves little known.

Independent of all theoreticals speculation, we can see

that: 1st., the heating temperat temperature; 3rd., the rate of coo factors in the heat treatment of steel, with a precision that the inspection showing. But to obtain any practic must have the different structures c sponding mechanical properties.

We have noticed, for example, increasing temperatures, that the v gradually increases, while the hard ishes. What will be the properties tures with ferrite? Experience alo manner.

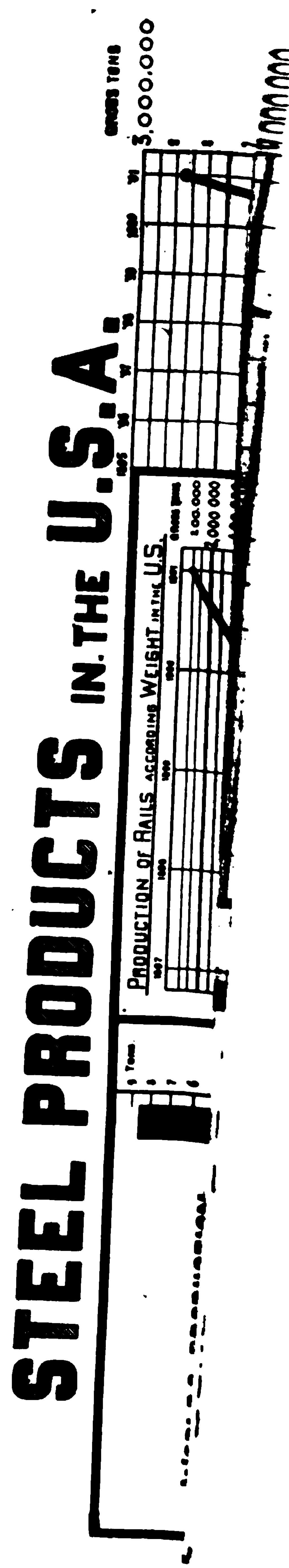
In the practical use of metallog every metal dealt with, a prelimina once made, it will be easy to tell wit heat treatment a finished piece has treatment, which is of primary impo the fixed rules. To remedy it, if responsibility of failures.

An excellent and very conclusiv given by M. Albert Sauveur, who of the Illinois Steel Co. a regular examination.

The comparison of the results the important work recently publis the auspices of the Society of Enc furnish useful information.

I wish to say again that for ind method that has been described, is Like the general rules of Analytica may be simplified, as the occasion an

This method is a method of inv ous when we are searching for the process will be much more rapid.



IRON ORE IN THE U.S.A.

MILLIONS OF TONS

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

The two hundred and thirtieth regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the society's house, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, December 16, 1902, at 8:15 o'clock, President Charles F. Scott in the chair and 112 members and visitors present.

The minutes of the preceding meeting were read and approved.

The Board of Direction reported that they had passed favorably on the following applications for membership, and present same to the society:

NAME.	OCCUPATION.	ENDORSED BY.
ROBERT M. ALLEN,	Draughtsman Westinghouse Machine Co., East Pittsburgh, Pa. h. 13 Moody Street, Braddock, Pa.	R. A. McKee, Richard Hirsch, E.S. McClelland.
WILBUR ALTMAN,	Mechanical Engineer Pgh. Shear Knife & Machine Co., 47th St. & A. V. Ry., City. h. 7344 Kelly Street, Pittsburgh, Pa.	Thos. Fawcus, H. M. Wilson, Richard Hirsch.
WM. JACOB AUBURN,	Draughtsman Westinghouse Machine Co., East Pittsburgh, Pa. h. 310 Pitt Street, Wilkinsburg, Pa.	E.S. McClelland, Richard Hirsch, R. A. McKee.
MINOT C. BLEST,	Checker Pressed Steel Car Co. h. 1720 Beuna Vista Street, Allegheny, Pa.	F. V. McMullen, S. B. Whinery, Richard Hirsch.
DAVID H. CHILD,	Chemist For Pittsburgh Reduction Co., New Kensington, Pa.	R. A. McKee, Richard Hirsch, C. W. Ridinger.
GEO. L. COLLORD,	Supt. Blast Furnace Clairton Steel Co.	J. M. Camp, Chas. H. Rich, C. W. Ridinger.
DAVID C. CREESE,	Supt Building Construction and Inventor the Creese Track Mover. 1945 Lithgow Avenue Allegheny, Pa.	G. K. Smith, C. B. Albree, Richard Hirsch.

CHAS. S. GOODRICH,	Ass't Gen. Supt. - The B. F. Goodrich Co. Akron, Ohio.	C. F. Scott, H. K. Hitchcock, C. B. Albree.
VASILI Y. GREBENNIKOV,	Mechanical Draughtsman Jones & Laughlin Co. h. 322 Lehigh Avenue, E. E. Pittsburgh, Pa.	E. F. Mould, W. P. Engleman, C. W. Ridinger.
ALFRED E. HESS	- Chief Engineer - Pittsburgh, McKeesport and Connellsville Railway Co. h. Connellsville, Pa.	L. B. Stillwell, E. W. Hess, W. G. Wilkins.
WALTER KENNEDY,	- Consulting Engineer - 611 Penn Avenue, Pittsburgh, Pa.	Harry Heffrin, F. H. M. Gerwig, A. N. Diehl.
HARRY A. METZLER,	Ass't Supt Building Cons'rction, h. 117 Fifth Avenue, Homestead, Pa.	G. K. Smith, C. F. Scott, C. B. Albree.
JOHN J. MUIR,	- - Mechanical Engineer - - with Julian Kennedy, h. 819 Maryland Avenue, Pittsburgh, Pa.	J. B. Hardie, W. S. Stevenson, G. E. Flanagan.
SAMUEL A. SCOTT,	- Chief Engineer - Monongahela River Coal and Coke Co.	E. J. Taylor, H. W. Patton, C. B. Albree,
EDWIN C. SHAW,	- General Superintendent - The B. F. Goodrich Co., Akron, Ohio. h. Akron Ohio.	H. K. Hitchkock, C. F. Scott, C. B Albree,
ARNOLD STUCKI,	- Mechanical Engineer - Pressed Steel Car Co. 1918 St. Clair Terrace, Allegheny, Pa.	H. H. Anderson, J.L. Klindworth, S. B. Ely.

Total 16.

It was voted that the Secretary cast a ballot electing the above sixteen applicants to membership.

It was then announced that Mrs. Foskett had offered the society an option on the property for $43,000, twelve thousand ($12,000) dollars of the amount to be paid in cash and balance on 5% mortgage. The matter was referred to the Building Committee and a motion was passed authorizing the committee to secure the option; expenses of same not to exceed $100.00.

The following papers were then read:

"Prof. John A. Brashear—"Astronomical Equipment for the Chilian Observatory."

SOME INTERESTING EXPERIENCES CONNECTED WITH THE MANIPULATION AND INSTALLATION OF CABLES.

BY H. W. FISHER.

While the manufacture of submarine cables was developing very rapidly about a half a century ago, it was not till the end of the seventies and early eighties that definite steps were being made to construct different types of cables to meet the requirements of the then infant electrical industries which have later grown to such giant proportions. Since that time the cable business has developed rapidly until now, when it can be considered one of our great electrical enterprises.

In substantiation of this some general figures relating to the history of the Standard Underground Cable Company may be of interest.

About ten years ago our business amounted to about half a million dollars per annum. This year it will be close to five million dollars and from the general indications it will probably be seven or eight million dollars next year. Lately we have been using at the rate of 2,000,000 pounds of lead and 750,000 pounds of copper per month.

On account of the great difficulty of getting copper wire on time, and in view of the great amount which we require for our business and the large demand there is for copper wire, we have recently put up one of the finest copper rolling mills and wire drawing plants in the country. The mill has a capacity of seventy-five tons per day of wire rods, and the new wire drawing plant when completed will be capable of drawing 100,000 pounds of different sizes per day.

After this brief statistical summary it may be of interest to trace the development of the more important types of cables.

TELEPHONE CABLES.

In the early days wires for this purpose were insulated with cotton and were formed into cables without pairing, after which the core was impregnated with an insulating compound, and either directly lead covered or pulled into a lead pipe. About this time it was found that paper possessed many desirable qualities as an insulating medium, and hence it began to be used. No. 18 B. & S. G. conductor was generally specified, and the electrostatic capacity per mile was about .18 M.F. As the telephone exchanges became larger it was found necessary to form the conductors into twisted pairs so as to eliminate cross-talk and also to reduce the electrostatic capacity so as to improve articulation.

Then came the celebrated Bell Telephone Conference specifications in which an electrostatic capacity of .08 M. F. per mile for No. 19 B. & S. G. wire was required. In order to meet these seemingly rigid specifications paper had to be formed so as to include as much air as possible, no insulating compound could be employed, and the cable core had to be directly baked out at a temperature above the boiling point of water just previous to the application of the lead cover. For a long time this form of cable remained a kind of standard with the Bell Telephone Company, but after the long distance telephone circuits began to come into use it was found desirable from an economic standpoint to use cheaper cables consisting of smaller conductors for local work and proportionately larger cables and larger conductors for long distance distribution through trunk lines. In explanation of this I might say that a large capacity interferes with articulation, while a large resistance diminishes the volume of sound, hence for long distance work—where the resistance is almost sure to be high—it is desirable to make the electrostatic capacity and conductor resistance of cables as low as possible.

There is a limit to the size of conductor that can be used because the electrostatic capacity increases rapidly with the size of conductor. Conductors as large as No. 11 have been, used but Nos. 18, 16 and 14 are more often employed for long distance distribution, and Nos. 19, 20 and 22 for local lines. For long distance distribution work we have made cables consisting of No.

14 B. & S. G., which had as low an electrostatic capacity as .0055 M.F. per mile.

In the construction of these kind of cables the method of applying the paper is very important for economic reasons, in order that the cables may be made as small as possible and yet meet the requirements of the specifications. This work has grown to such large proportions that from our factories we have shipped the equivalent of over 120,000 feet of 100 pair cable in one week. This means 24,000,000 feet of wire covered in one week.

ELECTRIC LIGHT CABLES.

In the early days a large proportion of cables employed were insulated with rubber, and many of these did not have any lead cover. As this form of cable was expensive, and when not lead covered did not resist very well the action of temperature and atmospheric moisture, rains, etc., cables covered with cotton and jute and saturated with insulating compound and lead covered began to be used, and gave very good satisfaction until the requirements demanded the use of a more dense and compact material, when paper saturated with insulating compound was employed. In the old days 2,000 volts was considered very high indeed. At this date the processes are so much improved that the manufacture of cables for 10,000 volts is an every day occurrence, such cables being tested to 25,000 or 30,000 volts at the factory and occasionally cables for much higher voltages are supplied. In the manufacture of electric light cables it has been found necessary to use a large factor of safety, because in the operation of electric light and power plants there are apt to be sudden impulsive rises of voltage due to the phenomenon of resonance.

To insure flexibility large size conductors are made up of a number of smaller wires in the form of a strand or wire rope. Some of these weigh as much as 6 or 7 pounds per foot. In the manufacture of electric light cables large quantities of Para rubber are employed. A given thickness of vulcanized rubber resists a given voltage better than the same thickness of paper, but on account of the great expense of rubber compounds, paper cables for the same voltage are cheaper than those insulated with rubber, and just as satisfactory.

NOTES ON THE DESIGN OF RIVETER YOKES.

RY CHESTER B. ALBREE.

There are three principal methods of driving rivets—by hammering by hand and finishing with a set or "snap"; by hammering with a pneumatic hammer, a device having a rapidly moving piston, striking several hundred blows a minute on a suitable die, or snap, inserted in the end of the cylinder this is a quite recent method, but for field work is rapidly superceding hand riveting. The large majority of rivets for structural, boiler and plate work, however, are driven by machines which squeeze or upset the blank rivet end to form a head. Compression riveters are of several distinct types; the oldest form is the hydraulic riveter, consisting of a cylinder and piston or plunger, operated by high pressure, carrying a suitable die. The work to be riveted is placed between the jaws of the machine, the made head resting in a suitable die, attached rigidly to the jaw or stake of the machine. Other machines are of the same general type, differing in the means for applying the power and the kind of motor fluid, as for instance, direct steam-driven or air-driven. Toggle joint devices, actuated by air, steam, electricity or belts. A late design uses an air cylinder, acting as a hydraulic intensifier, with provision to give a considerable travel at low pressure, followed by a short travel at high pressure.

In all of the compression riveters, of whatever type, the moving die is on one leg or jaw, and the pressure reaction is taken up by an opposed jaw. In general, the form resembles a letter U, the two legs being either in one piece or united by bolts.

This paper will discuss the design of a pneumatic toggle joint riveter, of 12-foot gap, made in one steel casting, of sufficient stiffness to drive rivets $1\frac{3}{4}$ inches in diameter.

The pressure required to close hot soft steel rivets has been determined quite accurately by Sellers & Co., of Philadelphia, by means of experiments with a hydraulic press, with pressure-re-

cording attachment. These tests have been fully described in the technical press in the past.

The net working result is that to close ordinary soft steel rivets, at bright red heat, with a round or button head, a pressure of 150,000 pounds per square inch of rivet section is required. For large rivets used in boiler work it is customary to heat the rivets as hot as possible, without burning them, in order that the material shall flow easily and completely fill the rivet holes. Under these conditions less power is required to close them, and a pressure of 129,000 pounds per square inch, rivet section, has been found ample.

The pressure required to drive a 1¾-inch diameter rivet, with round heads, is therefore the area 2 and 4-10 square inch by 125,-pounds, or 297,600 pounds—say, in round numbers, 300,000 pounds.

With the type of toggle joint used, assuming a cylinder 18 inches diameter, 12-inch stroke, with air at 80 pounds pressure, we have a total cylinder pressure of 20,320 pounds, or, in round numbers, 20,000 pounds.

In the force diagram of the toggle used (as per the diagram Fig. 1) we note that the strain, when upper end of the side links have traveled 13-16 of the total distance, is about 15 times the cylinder pressure, or 300,000 pounds—the required amount.

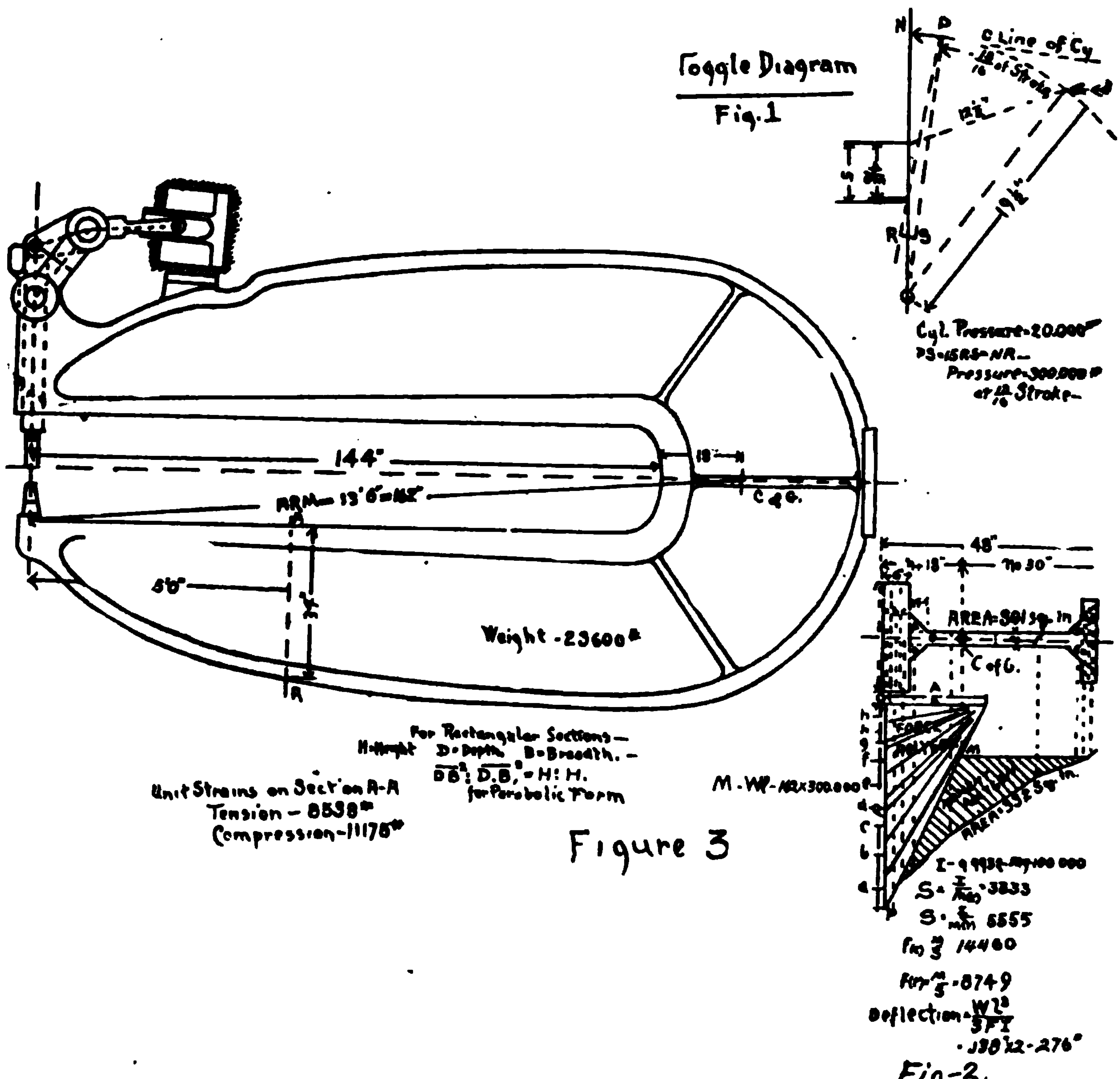
Observing the corresponding travel of the ram, we see that it has traveled to within 1-16 inch of its total travel of 5 inches, or practically the whole distance, hence the rivet head is practically finished at this point. In toggle joints the final pressure becomes theoretically infinite and the plunger travel zero.

The actual pressure on the rivet, however, is measured by the stiffness of the yoke, which yields somewhat under the stress.

In designing the yoke we aim to get the required stiffness with the least weight, and assume that with yokes of well-annealed O. H. steel castings, we may safely use unit strains of 10,-000 pounds tensile and 14,000 pounds compressive. Castings, pulling 60,000 to 65,000 pounds, with elastic limit of 30,000 to 35,000 pounds, are used. The gap being 12 feet, or 144 inches, the depth at back of yoke was taken as 1-3 of the gap, or 48 inches. This

proportion can be varied by changing the proportions of cross section, but experience has shown this proportion to give economical results.

The section was made an irregular I beam form, having a tension head much larger than the compression end. We assume a section that looks about right, and by the well-known principles



of graphic statics, divide it in layers (see Fig. 2), determine area and center of gravity of each, and lay off the areas to some convenient scale and construct the force diagram, making the pole distance one-half the length of the load or area line.

This forms always a right-angled triangle, of which particular construction further mention will be made later. We then

construct the equilibrium diagram, finding the resultant and locating the center of gravity of our section.

In Fig. 3 is shown an outline of the yoke, which you will notice is curved where the two arms or jaws join. The exact mathematical determination of the strains in a curved beam of this shape are very complex. The problem has been studied by several mathematicians, including an exhaustive article published last year in the transactions of the Deutches Eisenhuttenleute Verein; but in practice I have assumed that if the arm of the bending moment were taken as the diagonal from the end or nose of the jaw to center of gravity of the median section at the center of the curve, then the increase in length over the straight gap of the machine would compensate for the curvature and actual results in practice, as well as comparison with the mathematical solution, seem to justify the assumption.

Having determined approximately the length of the moment arm, we then have our bending moment, which for a beam loaded at one end and fixed at the other, is simply Wl— or 300,000x162 inches.

Next determine the moment of inertia of the assumed cross section, which may be done analytically, arithmetically or graphically.

The graphic method is simplest, and we use a method shown in Molesworth's handbook, 1889 edition, which is simpler than any other. Although most of you are probably familiar with it, yet for the benefit of those who have not used it I give the proof from Merriman and Jacoby's treatise on Bridges and Roofs—Part II, Graphic Statics, 1902 edition:

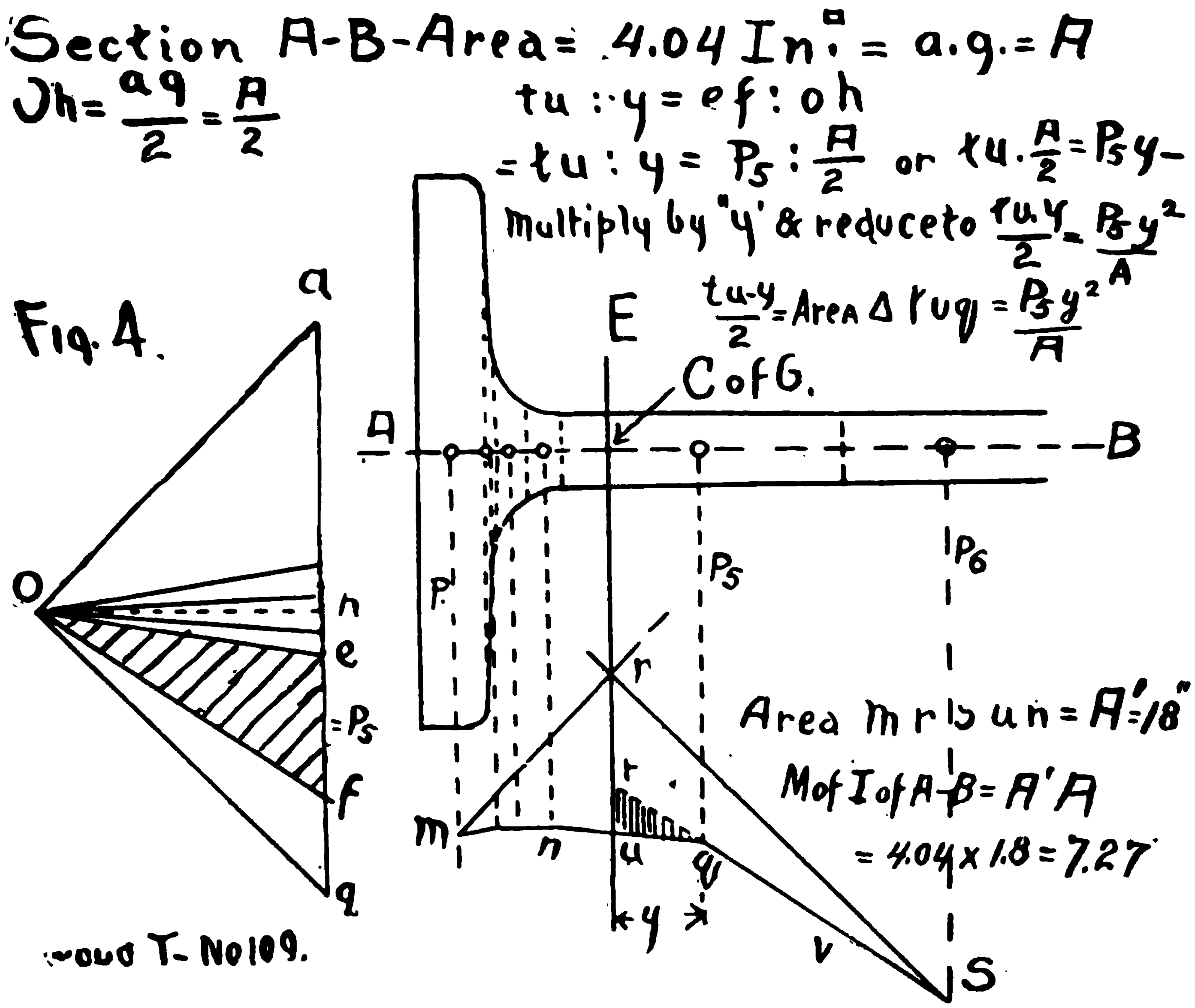
"We assume in Fig. 4 a standard T section, divide into convenient sections, letting areas be represented by force lines P^1 P^2—P^5.

"Lay off the load line—ag—parallel to forces P^1—P^5 and proportional thereto, to some convenient scale; make the pole distance oh=$\frac{1}{2}$ ag=A2, and construct the force polygon—oag—which by construction is a right angle triangle.

Construct the equilibrium polygon m r s and determine the center of gravity of the section A—B. Produce sq. to meet axis

E at t—. Then triangles qtu and ofe are similar, as sides are parallel by construction.

Let oh be the altitude of triangle oag and y the altitude of triangle qtu; hence—tu :y=equals ef :oh—but ef=P^5 and oh=$\frac{1}{2}$A. or tu :y=P^5 :A-2. Multiplying this equation by y and reducing, we have $\frac{1}{2}$tu.y=P^5 Y^2-A, but $\frac{1}{2}$tu.y=area of triangle qtu.



If the area P^5 were of the width dy its moment of inertia would be P^5 Y^2. In like manner, the moments of inertia of each force P^1 P^2 —— P^6 can be determined, and also the corresponding triangles and there sum, the moment of inertia of the whole section A—B would therefore be the total area of section multiplied by the area of the elquilibrium polygon. This latter area,

denoted by A_1, can be determined by a planimeter or otherwise, and we have—$I = A^1A$. Q. E. D.

Referring again to Fig. 2 and using the method just explained, we see the area of the section is 301 s. in. and of the moment polygon, 332 sq. in., and their product about 100,000 as the M. of I.

In the well-known formula for the section modulus—$S = I/N$—and for extreme fibre strains—$f = M/S$—we find for tension 8,749 lbs. and compression 14,460 lbs., which are safe, and as a check, and to determine the deflection we use the formula $\frac{Wl^3}{3EI}$ = deflection, using E as 29,000,000, and find the deflection of the beam, supposing the section uniform throughout, to be .138 inches. As there are two arms, equally strained, the total deflection is .276, or a little over ¼ inch. In actual test the measured deflection was 7-16 inch, probably due to the tapering ends being designed a trifle light to keep outer stake small enough for certain work to be done. As this machine has been in constant use for over two years, and no permanent set has taken place, we feel assured of the results and methods.

Having fixed the median section, we design each arm to be a beam of uniform strength. Such beams may be various shapes, but the design chosen is a beam of I beam section, in general similar to the median section, varying in size according to the parabolic curve, but having the inner edge on a straight line.

The exact proportion of depth, width, thickness of flanges and web might be figured exactly by a more expert mathematician than the writer, but the method adopted was to use the parabolic form for a rectangular cross section, and then finding the unit strains for different points and modifying the cross sections until these unit strains were practically the same as found for the median section.

In large castings blow holes or other defects sometimes occur, and often exist inside, but by omitting as far as possible cross webs and irregularities, fairly good castings can generally be obtained. In several hundred yokes that we have had, but two or three have failed under pressure, and then from blow holes at critical points.

This particular riveter is used for riveting marine boilers 10 to 16 feet diameter, having plates from 1 to 1¼ inches thick, and practically no rivets have had to be caulked to prevent leakage. For large diameter rivets it is best to allow the pressure to remain on the rivet until the steel is black, for if pressure is taken

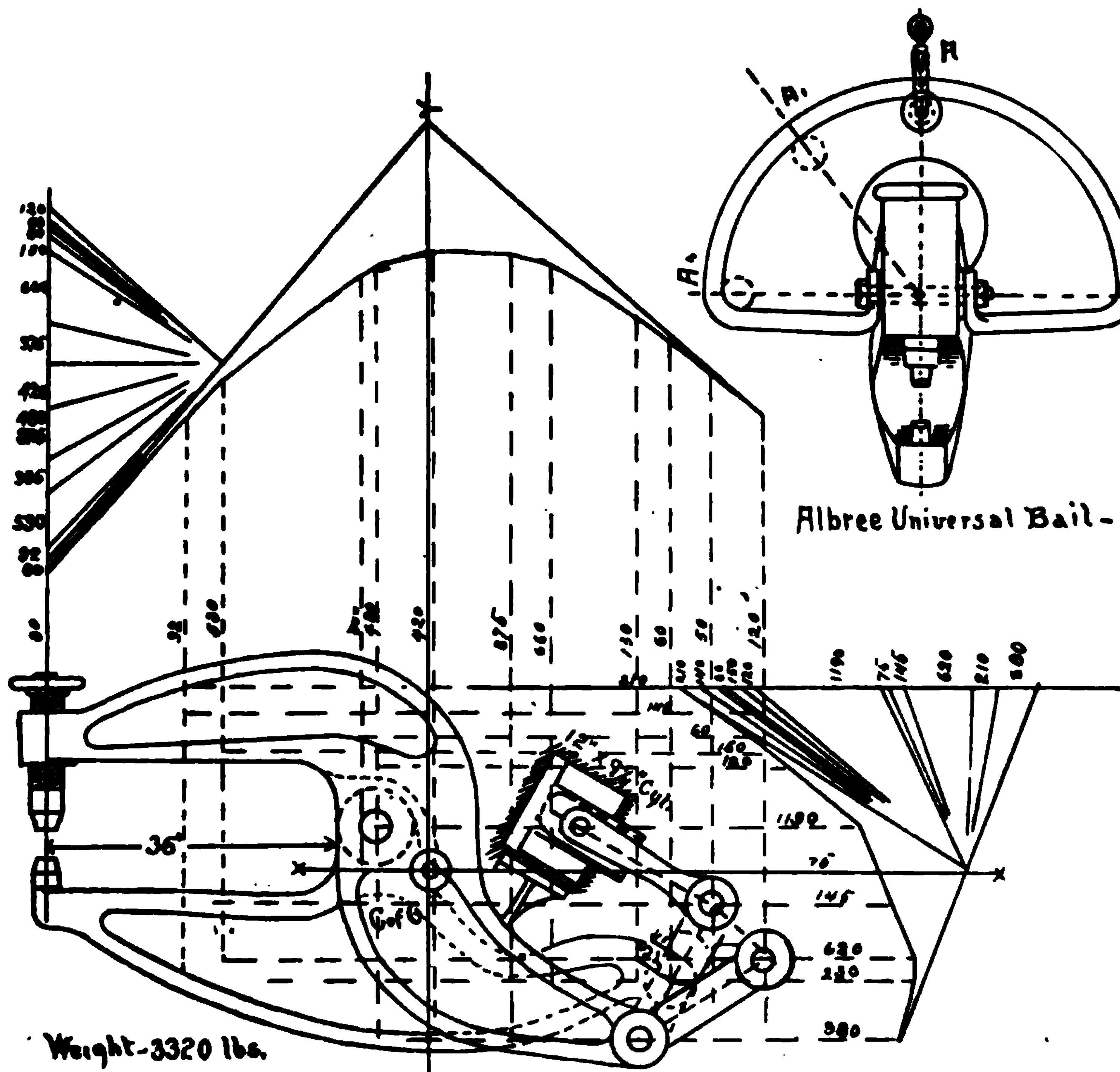


Fig. 5
36" Nipper Riveter—
for 1⅛" Rivets—

off while rivet is still red hot the spring of the heavy plates will often stretch the rivet and a leak will be the result.

In small portable riveters it is often desirable to be able to use them in other than vertical planes, for crooked work. This has been generally accomplished by a double worm gear attachment forcibly holding the yoke in any desired position. The writer devised a special form of vail, called the universal bail, to accom-

plish this result in a simpler manner, permitting of more rapid adjustment.

In mechanics we read that a body will be in equilibrium if supported from above or below, from its center of gravity. Hence if a riveter were suspended from trunnions passing through the absolute center of gravity of the machine it would be in equilibrium, in a vertical plane, if the axis were parallel to the horizon. If the bail, instead of having the usual straight sides, is made in the form of a semi-circle, whose center is the center of gravity of the machine, then if the bail be suspended from any point of the arc, the machine would still be in equilibrium.

By suspending the bail on a trolley attached to a swivel above, the bail can be rolled around and the riveter worked at any angle in any plane.

To determine the exact center of gravity in advance of actually building a machine is necessary in order to locate the trunnion axis on the body of the machine in a convenient place and to provide bosses for trunnions on the pattern.

After designing the general layout of a machine, as in Fig. 5, bearing in mind the probable location of the center of gravity, we mark off on the plan various convenient parts whose weight can be determined, and ascertain as nearly as possible the center of gravity of each such portion. We then construct the force diagram and determine a line containing the center of gravity for one position. We then go through the same process, but for a position at right angles to the first, finding the center of gravity line for this position. The intersection of the two lines locates the absolute center of gravity, and as the machines are symmetrical as regards a median plane lengthways of the yoke, the determination in the third plane is unnecessary.

It is obvious that for machines having deep throats the center of gravity tends to come more nearly to a middle position between the arms. As this location does not permit of placing the trunnions without interfering with the gap of the riveter, it is necessary to add weight to the upper side, at as great a distance from the jaw opening as possible in order to locate the trunnions on the body of the machine. In practice we find that for riveters over 48-inch gap, the extra weight and bulk are so great as to make such machines impracticable.

EARLY EXPERIENCES IN TRANSPORTATION.

BY ANTES SNYDER.

My attention was early called to this question of transportation in a very practical way. When a boy, living in the village of Selinsgrove, on the Susquehanna, I worked in a foundry at 25c per day. There was a failure of the crops, whether it was general or local I do not know, but it made no difference which it was, as we had then only the Pennsylvania canal, no railroads, and our country roads were little better than streaks of mud. Though there might have been an abundant harvest within a few hundred miles we could not have availed ourselves of it for want of transportation. The wheat for the bread of that town and others of like situation was brought from the Mediterranean by vessels to Philadelphia and there loaded on canal boats and distributed to the towns along the canal. A bushel of wheat cost $2.25, it took nine days' work by me to buy a bushel of wheat and one month of my labor was represented by three bushels of wheat.

I did not at that time bother myself about the laws or principles governing this matter, their practical application was enough for me, but as I grew older this matter came up in my mind and induced me to look into this question of transportation. Whether it influenced me so as to determine my future and make an engineer and railroad man of me I cannot say, it did not do so at that time, as the highest paid man in that foundry received $2.50 per day and the height of my ambition was to reach that exalted position.

Such a state of affairs will never in all human probability occur again, when our railroads haul a bushel of wheat from Chicago to New York city for 15 cents.

I understand that this is to be an experience meeting, a kind of a go-as-you-please meeting, and I have nothing in my experience different from that usual to the ordinary construction engi-

neer, and so I have not prepared any formal paper. As I cannot give you anything of interest in my own experience, I am forced to fall back on the experience of the early engineers who are not here to speak for themselves.

When the commonwealth opened the Philadelphia and Columbia Railway, the theory was that the State furnish the road way and that any one that pleased could furnish his own vehicle and motive power and use the railway whenever he pleased, by paying the State tolls for its use, just as the turnpikes of the day were used. But it was soon discovered that a certain character of vehicle was necessary and that rules and regulations as to times and manner of using the railways were absolutely necessary in order to their successful operation. The ordinary shippers found it too expensive to fit himself with the necessary plant, and that they could get this transportation done by large and well-equipped shippers much more cheaply than they could do it themselves, so that in practice the business drifted into the hands of a few individuals and companies, who did this service for the many. The railway as constructed was intended for the horse as motive power, though the locomotive was being introduced as an experiment shortly after the railway was completed.

The following among the rules and regulations adopted by the Canal Commission for the regulation of the railway may be of interest:

"Section 92.—No car shall carry a greater load than three tons on the Columbia and Philadelphia Railway, nor more than three and one-half tons on the Portage Railway, nor shall any burden car travel at a greater speed than five miles per hour, unless the car body and load shall be supported on good steel springs."

"Section 108.—It shall be the duty of the conductors of cars moving with less speed upon the railways, upon notice by ringing a bell, blowing a horn, or otherwise of the approach of a locomotive engine or other cars moving in the same direction at a greater speed, to proceed with all possible dispatch to the first switch in the course of their passage and pass off said track until said locomotive engine or other cars moving at greater speed can

pass by. The conductors of the slower cars are directed to open and close the switches so as to leave them in proper order. Any person who shall refuse or neglect to comply with the provisions of this regulation shall, for every offense, forfeit and pay the sum of ten dollars."

It must have been a very interesting and novel sight, indeed, while the horse and locomotive were used indiscriminately on the same track and were struggling for supremacy as the future motive power of our railroads, and the approach of the locomotive engine was heralded by the tooting of a horn. Even at that time the right of way was given to the fast horse.

The railways when first introduced had to meet great opposition from the ignorant, prejudiced and self-interested, and what that was the following will show:

In a speech before the House of Commons of Great Britain, in opposition to the granting of a charter to the Liverpool and Manchester Railway, Admiral Sir Isaac Coffin said in part:

"I would not consent to see the widow's premises and strawberry beds invaded, railroad trains would take many hours to perform the journey between Liverpool and Manchester, and in the event of the scheme succeeding, what, I would like to ask, was to be done for all those who had advanced money in making and repairing turnpike roads? What with those who still wished to travel in their own or hired carriages, after the fashion of their forefathers? What was to become of the coachmakers, harness-makers, coachmasters and coachmen; innkeepers, horse breeders and horse dealers? Was the House aware of the smoke and the noise, the hiss and whirl which locomotive engines, passing at the rate of ten or twelve miles an hour would occasion? Neither the cattle plowing in the fields, nor grazing in the meadows, would view them without dismay. Iron would be raised in price 100% or more probably exhausted altogether. It would be the greatest nuisance, the most complete disturber of quiet and comfort in all parts of the kingdom that the ingenuity of man could invent."

Now, our good friend, Captain Dravo, whom we all respect and admire for his loyalty to his first love, the river interests,

when he depicts the dire calamity that will result to every home and every industry in the Ohio and Mississippi valleys from the introduction of a few bridge piers in the beds of these rivers, is like the good old English admiral, perfectly sincere in what he says, but equally mistaken in his prediction.

Captain Jones—"Professional Reminiscences."

It was voted that a committee of three be appointed to audit the books of the Treasurer. The President appointed as this committe Messrs. Lewis, Barnsley and Covell.

A vote of thanks was tendered the several gentlemen for the very interesting and instructive papers of the evening.

Meeting adjourned at 10:45 o'clock.

CHARLES W. RIDINGER,

Secretary.

OFFICERS FOR 1903.

GENERAL SOCIETY.

PRESIDENT.

CHAS. F. SCOTT.

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F. C. PHILLIPS, Term expires 1903.

CHESTER B. ALBREE, Term expires 1904.

DIRECTORS.

JAS. M. CAMP, Term expires 1903.

RICHARD HIRSCH, Term expires 1903.

C. B. CONNELLY, Term expires 1904.

CHAS. HYDE, Term expires 1904.

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ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

ANNOUNCEMENT.

In the future the Society will mail to its members and correspondents, postage prepaid, ten monthly pamphlets yearly; each one including the minutes of and the papers read at the regular meeting, and meeting of the Chemical Section.

The pamphlets are for sale at 50 cents each. Subscription price, $5.00 per annum.

In addition, any paper which the author desires to be distributed before being read will be mailed separately.

The following Rules of the Board of Directors are in force:

No paper shall be published in any journal or magazine before its appearance in the Society's Proceedings, without the sanction of the Board.

An author of a paper is entitled to twenty-five copies, if printed. In addition he can purchase fifty or more copies extra at first cost to the Society, plus 10 per centum, provided the order is forwarded before the type is distributed. These papers can be issued with pamphlet covers when desired.

With the publication of Volume X, the printing and binding of our TRANSACTIONS as an Annual, by the Society, ceased. The paging of the Monthly numbers, however, will be made consecutive, and at the end of the year a title page and index will be provided, so that members may have them bound into a volume uniform with preceding ones.

Copies of Volumes will be mailed to members who are in good standing, on receipt of prices as stated below, for paper covered or 25 cents extra for cloth bound.

Vol. I, $1.50, Vol. IV. $2.00, Vol. V, $1.00, Vol. VI, $1.00, Vol. VII, $1.50, Vol. VIII, 50c., Vol. IX, 50c., Vol. X, 50c. Complete sets of Vols. XI and XII, unbound, $2.00 each.

A few copies of single papers unbound will be carried. These can be purchased by members for 25 cents each.

In order to keep the cost of publication of papers within the limits of the resources of the Society, the Board desires to impress on all authors the necessity of restricting their illustrations to single page and to a limit of three pages. The Board reserves the right of supervision of papers and illustrations.

In regard to preparing drawings for publications: Tracings only can be used, and these must be in strong lines and strong lettering. The author must make all tracings subject to reduction to 6½ inches in one dimension. The size of a single page of our publications is 6½x4 inches. Pull outs may be in multiples of the 4-inch dimension, but must not exceed 6½ inches in the other. Many tracings may be made so strong by using black ink and wide lines that reduction is possible across the page. All tracings can be reduced six to one. [Before any illustrations are reproduced the author must submit his tracings to the Board of Direction.]

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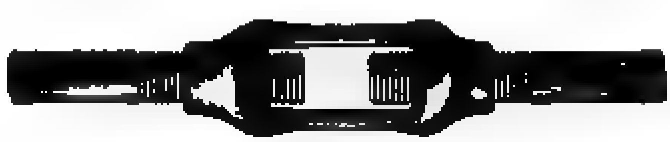

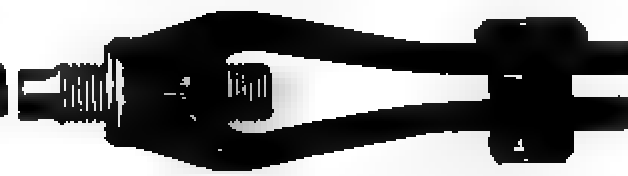

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